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Editorial Comments

Colonial Harbours and Wharfs.

Among the papers presented at the Conference on Civil Engineering Problems in the Colonies, which was held in July 1950, was one by Mr. R. D. Gwyther, which was devoted primarily to Dock and Harbour Engineering. It is, however, of general interest to all who are concerned with port installations, layout and equipment, and accordingly, by kind permission of the Institution of Civil Engineers, under whose auspices the Conference was convened, we are reproducing the paper, and the discussion which followed, in full in this and following issues.

In the paper, the author compares the facilities usually afforded by deep-water berths with the handling of goods between ship and shore by lighterage. As might be expected, the latter was the method adopted at a number of Colonial ports and harbours which were originally constructed many years ago, but several instances are given of the modern tendency to provide deep-water berths, which characteristic, it may be remarked, is not confined solely to ports in British Colonies or Mandated Territories. Generalization as to the appropriateness of such facilities is unwise, as so much depends upon the geography of the port in question, but some notable examples of the efficacy of lighterage in varying circumstances are, the Ports of London, New York, Hamburg, Calcutta and Rangoon, where large proportions of the cargoes handled are dealt with from one or both sides of vessels, i.e. either while at berths or lying at moorings.

In respect to cranage, in almost every instance quoted by Mr. Gwyther, quay cranes were provided, and there seems to have been no question of there being any completely efficient alternative. On the other hand, readers will remember that our issue for July last contained a description of the recently completed Port of Monrovia, with its deep-water open piled wharf, on which no quay cranes (except a heavy lift) were provided by the Americans, all transhipment of cargo being carried out by ship's gear. The two systems are thus brought into sharp comparison by the two articles.

The solid block work type of quay wall is over two thousand years old, but it has a great deal to recommend it, and, in many suitable situations, it is still much favoured by many British, Colonial and Foreign engineers. At the same time, we think that too conservative a line should not be taken in respect to some of the more modern designs of heavy decked reinforced concrete piled structures, the merits of which are by no means negligible.

The question of transit sheds, and whether one or more stories should be provided, is also controversial to some extent. General practice tends towards single-storied sheds, and indeed, where adequate space is available, any advantages possessed by multi-storied sheds are not readily apparent. In American practice, which, as stated above, does not usually favour the installation of quay cranes, single-storied transit sheds are almost universal.

Mr. Gwyther's paper is a valuable contribution to the study of the problem of Quay Layout, which has been given some prominence in this Journal, since the article by Mr. Hermann Jansson appeared in our January 1950 issue. This and subsequent articles have evoked considerable interest among those who contend that the key to increased efficiency in port services is greater uniformity in freight handling methods and facilities.

Growing Interest in Dock Labour Schemes.

The question of the permanent and full-time employment of dock workers is a matter of international importance which has frequently been referred to in these columns. It is, therefore, of interest to learn that many schemes, largely based upon the successful United Kingdom Decasualisation experiment, are being considered abroad, and, in some cases, have already been carried into effect.

In our June 1948 issue, mention was made of a decasualisation scheme for Singapore, and since then, somewhat similar projects have been mooted by a number of other countries, including India, Burma and Israel.

In India, the Central Government recently agreed to negotiate with the Bombay Dock Workers' Union concerning its demands for the decasualisation of dock labour throughout the port, increased wages for dockers handling food grain ships, and discussion of the question of bonus payments. The Government's decision followed a general meeting called by the union, at which more than 5,000 port employees voted in favour of serving a fourteen-day strike notice on their employers should their demands for arbitration not be met.

In Burma, according to a report issued by the "International Transport Workers' Federation," the Burmese Government has approved plans for providing greater regularity of employment for dock workers by the creation of a permanent labour force, with adequate remuneration, health provisions and related conditions of employment. The programme is in conformity with the enabling provisions of the Dock Workers (Regulation of Employment Act) passed in 1948, after the experience of continual under-employment on the waterfront had made evident the need for the introduction of a system of decasualisation.

At present, the new scheme applies only to the Port of Rangoon, but eventually it will cover all the ports in Burma. The number of registered port workers is to be limited, and each will be guaranteed payment for 14 days per month, at the rates applicable

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to his working category. Working hours are limited to 8 per day and 48 per week, plus a maximum of 2½ hours overtime per day. In addition, minimum wages rates and cost-of-living allowances have been estabished and provision made for the direct payment of wages to each worker. The scheme is administered by a Board comprising a Chairman, nominated by the Government, and three members representing employers, and three representing the workers.

Improved conditions for dock workers in Israel have also been agreed between the General Federation of Jewish Labour and the Port Authorities of Haifa and Tel Aviv-Jaffa. In this instance, an important item deals with the status of the worker. Between the group of permanent employees and casuals engaged on a daily basis through the Labour Exchange, there has, up till now, been a third group of workers guaranteed a minimum number of work days a month, but not full employment. This group is now being transferred gradually to the permanent register. In addition, the entire wage structure has been revised and based on clearly defined grades related to specific tasks.

This world-wide trend towards a higher standard of employment conditions is encouraging, and should go far towards mitigating discontent and subversive activities in an industry which is essential to the economies of all nations.

Technical Mission to Study Inland Water Transport.

Twelve delegates from six far Eastern countries—Burma, India, Indonesia, Pakistan, Thailand and Viet-Nam—are visiting Europe and North America during the months of August, September and October, to observe new methods in river and canal transport. This tour, which is sponsored jointly by the Technical Assistance Administration and the Economic Commission for Asia and the Far East, was recommended by an E.C.A.F.E. Committee, who proposed the formation of "a team of technical inland water experts, drawn from several countries of the region, to study abroad the technical advances in inland water transport methods, and thereafter submit a detailed report . . ."

The party will visit the most important waterway installations in France, Switzerland, Germany, Holland, Belgium and the United Kingdom, and their programme will include a demonstration of the methods used to maintain uninterrupted river traffic during the construction of a hydro-electric station at Birsfelden, and how small barges operate on the Lahn and Ruhr. They will witness a tug-boat demonstration at Dordrecht and participate in trial runs with towed barges, and also observe how barges are operated along the French Rhine (including towage from the banks). A section of the Canal d'Alsace, now under construction, will also be inspected.

In the United Kingdom, their schedule includes a demonstration of the "Bantam" pusher-tug at Brentford, a visit to a Thames yard where a new type of steel barge is being built, the demonstrations of over-side unloading of barges in the Port of London, and of "compartment boats" on the Aire and Calder Rivers, and visits to an experimental basin at Glasgow, and the shipbuilding yards at Glasgow and Hull.

The primary aim of the tour is to study improved types of craft, which would be most suitable for introduction into Asia and the Far East, and also to seek ways of improving Far Eastern waterways. One problem of particular interest is the need to increase the carrying capacity of the small craft known as "country boats," the most common type of river boat used in those regions. The mobility of these boats is poor, since they are dependent on wind and current, hence the need for the studies mentioned above.

Arrangements have been made to ensure that the party will consult with government officials, technicians, transport operators, and engine manufacturers in all of the countries visited, and following the conclusion of the tour, it is intended that similar demonstrations will be given on a selected stretch of a waterway in the Far East.

British Transport Commission.

The 1950 Report of the British Transport Commission, which was published recently, and upon which we commented in our last issue, has been the subject of a debate in Parliament. During the debate, responsible advocates were heard of a proposal to wind up the functional Executives, and replace these by regional organisations, operating both railways and nationalised road transport. Under this proposal, the private road hauliers would be given considerably greater freedom, and more efficient operation of the nation's transport facilities would be expected to result from the consequent competition. No direct reference was made to the management of Docks, Canals and Canal carrying organisations within the regions, but it is hoped that those docks which have been independently managed in the past, in an efficient manner, would remain so; a progressive policy for the canals is hardly likely to follow control by predominately railway interests. Since it is vitally important that management of both docks and canals should be such as to ensure the greatest enterprise, which would require some measure of independent executive control, these proposals need further clarification.

Meanwhile, the announcement was made that the new Charges Scheme, promised for August 5th, is to be delayed while discussions take place between the Commission and coastal shipping interests. The Chairman of the Commission is said to welcome this opportunity of a little further time until the end of the year, before release of this Scheme. Since this Scheme is expected to include an increase in rates for mineral traffic, it will be of great importance to inland waterway interests.

Shortly after the occasion of this debate, the Minister of Transport stated that he was examining proposals about the future of derelict canals; these had been submitted to him by committees of the Association of Municipal Corporations. While a decision upon this issue is urgently necessary, it cannot in itself be regarded as a forward development. As the railways appear to be in the unhappy position of having to refuse traffic, while simultaneously losing money upon their operation, it is surely a most opportune moment to adopt a courageous and progressive policy in inland water transport, and also to give greater encouragement to coastwise traffic.

Navigation Locks in America.

In previous issues of this Journal, for the benefit more particularly of those readers who do not have the facilities for examining the International Navigation Congress Proceedings, we have, from time to time, reprinted papers of general interest. In our May 1951 issue, we published an article describing the design and construction of locks in America of moderate lift, and in this number will be found a paper dealing with some examples of navigation locks of high lift on American waterways.

Although the Report was prepared for the proposed Berlin Congress in 1940, it was presented, without modification, at the Congress held in Lisbon in 1949, and readers are reminded that the October 1949 issue of this Journal contained a review of the papers then presented. The General Report by Mr. Alberto Abecasis Manzares upon the Second Question—Means of Dealing with Large Differences of Head—was included in that review, and his Report may profitably be referred to again.

While the locks specifically described in the papers are situated upon Inland Waterways, they are, however, of large dimensions, and the problems of foundations, design, construction and operation are to a great extent similar to locks for ocean-going vessels, and consequently they will be found to be of considerable interest to dock engineers.

Freight Handling.

Towards the end of July last, the Anglo-American Council on Productivity published the report of the team which, during the summer of last year, studied freight handling methods in ports of the United States of America.

The subjects of mechanization, the speedier handling of cargo, and of delays in the turn-round of ships, are of growing importance in almost every port. We are, therefore, devoting some attention and study to the report referred to above, and propose to publish in our October issue, a review of those features which correspond, in some degree, to comparable conditions in British ports, adding our comments upon the American methods and the suggestions put forward by the British team.

Colonial Harbours and Wharfs

Some Notes on Recent Developments*

By R. D. GWYTHER, M.C., M.Sc., M.I.C.E.

Introduction

THIS Paper was primarily intended to deal with problems arising in connexion with harbours in the Dominions and Colonies. The Author has, however, deviated from the strict sense of the word "harbours" and has included a description of how the design, lay-out, construction, and equipment of wharfs are affected by the requirements of modern ocean-going vessels of deep draught and, in particular, by the necessity of obtaining a quick turn-round or a short stay at intermediate ports. Most colonial harbours, both natural and artificial, have been described from time to time in the Journal of the Institution and any further description here of their breakwaters or natural environments would be but repetition. On the other hand, short descriptions of three deep-water wharfs now in course of construction in the colonies may be of interest, since they show the lay-out entailed, in each case, on account of the local conditions and the requirements of the colony, and also show the type of construction adopted. For comparison with present-day design and modern shipping requirements, an account is also included of a rather unusual type of wharf which was constructed in the West Indies during 1886-88.

Harbours in general can be classified under the following three categories :—

Natural or landlocked harbours.—These do not necessitate protective works and are formed entirely by an inlet from the sea or by the estuary of some large river; this type of harbour requires only docks or wharfage, together with the usual harbour facilities, to provide for the development of the trade of the surrounding district. The following are typical examples : Freetown, Sierra Leone; Kingston, Jamaica; Kilindini, Kenya; Port of Spain, Trinidad; Dar-es-Salaam and Mtwara, Tanganyika; Sandakan, North Borneo; Hong Kong; Sydney, New South Wales; and Hull and Glasgow in Great Britain.

Protected harbours.—These are formed in bays or other indentations of the coast and give some protection from wave-action, by means of a breakwater or entrance moles, to vessels using or entering the port. The following are examples of protected harbours : Grand Harbour, Malta; Haifa, Palestine; Lagos, Nigeria; Cape Town; Singapore; Durban; Gibraltar; and Portland, Plymouth, and Sunderland in Great Britain.

Artificial harbours.—These have to be created when there is no pronounced natural feature and breakwaters have to be constructed on an almost open coast-line; examples are : Colombo, Ceylon; Takoradi, Gold Coast; Madras, India; and Dover, England.

Many of the Dominions and Colonies are fortunate in having harbours which are natural or which can be protected by breakwaters without excessive expense. Some colonies, however, such as Cyprus and Barbados, have no natural bay or inlet which could readily be developed for the accommodation of deep-draught ocean-going vessels, although Cyprus has the small artificial harbour of Famagusta with a water-depth of 24-ft. Ceylon is in much the same position and the only natural harbour in the island is Trincomali, which is used as a naval base and is not available for trade purposes.

Wharfage and Lighterage

In a great number of colonial ports, the handling of goods between ship and shore has been, and at the present time is being, carried out by lighterage. Shipping companies, and especially ship-masters, prefer to berth alongside a quay and handle cargo by means of wharf-side cranes or, if necessary, with their own gear. Lighterage is largely being reduced owing to the increased cost of labour and, more particularly, because of strikes by lightermen, tugmen, and stevedores, which frequently interfere with the working of a port. Lighterage entails increased handling, more liability to breakage, greater opportunities for pilferage, and resulting increases in costs and insurance. In some ports, the local lighterage contractors are opposed to the construction of wharfs, in spite of their development value. This opposition has recently declined and wharfs have been, or are about to be, constructed in several ports where, hitherto, lighterage has been the only means of transporting cargo between ship and shore.

At Colombo, for example, a comprehensive scheme of wharfage, including berthage for at least twelve large ocean-going ships, has been prepared and will shortly be put in hand. Five of the berths are intended for general import-cargo three for large passenger-cum-cargo liners, two for coal, phosphates, etc., and two for oil tankers, in a separate dock. The design of the wharf-side sheds is still under consideration but, for general transit-cargo, the large-span single-storey shed is preferred.

The port of Kilindini, Kenya, abandoned lighterage many years ago and embarked on a scheme of deep-water berthage shortly after the 1914-18 war; 3,000-ft. of wharfage was provided in three instalments and was sufficient to accommodate five or six large ocean-going vessels. This wharf-wall was constructed in concrete blocks laid in horizontal bond. An oil-berth was provided, quite separate from the main berthage. During the 1939-45 war, another berth was built in reinforced concrete.

Port of Spain, Trinidad, is another harbour where wharfage has superseded lighterage. Proposals for constructing deep-water berths at Port of Spain have been under consideration since the end of the nineteenth century, but it was not until 1935 that the existing deep-water wharfage was commenced; it was completed in 1939. The wharf is 3,170-ft. long and will accommodate five or six large vessels. Storage is provided by five sheds.

Just before the 1914-18 war, a deep-water wharf was commenced under direct labour at Freetown, Sierra Leone, but the war put an end to the project; the plant was dispersed and the scheme was shelved. During the 1939-45 war, aerodromes and other war-emergency projects were put in hand in the Colony and there was neither plant nor accommodation for dealing with heavy lifts. The use of Freetown harbour as a naval base created an immediate demand for deep-water berthage. Provision is now being made to accommodate two or three vessels at a wharf, 1,200-ft. long, with three sheds; two of the latter are single-storeyed, but the third has a second storey for offices, etc.

Lighterage at Dar-es-Salaam, Tanganyika, is shortly to be reduced considerably by the construction of berths for ocean-going steamers. A scheme for accommodating deep-water vessels alongside a wharf is to be put in hand and will consist of 1,800-ft. of blockwork wall with two double-storey sheds, sufficient for two large ocean-going vessels, or possibly three smaller vessels. In the light of experience gained at other ports, the project now to be put in hand is likely to be extended when the advantages of alongside berthage are realised.

Mtwara is a port which is being brought into existence in connexion with the development taking place in the southern area of Tanganyika. It has a magnificent land-locked harbour, with an entrance channel about 1,000-ft. wide and between 56-ft. and 60-ft. deep. There had previously been insufficient trade to justify any wharfage or lighterage, and so it had been possible to develop the port, from the start, to deal entirely with one industry and its allied requirements. A deep-water blockwork wharf, which is being constructed, will allow practically unlimited extensions for ordinary trade. In addition to the port facilities, about 120 miles of metre-gauge railway is being laid, which, together with the harbour, will

*Paper presented to The Conference on Civil Engineering Problems in the Colonies, July 1950, and reproduced by permission of The Institution of Civil Engineers.

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be of great assistance in developing the southern province of Tanganyika.

At Lagos, Nigeria, wharfs have always been available for dealing with cargoes, and so lighterage has practically never been practised. The wharfs were originally of the openwork type and were situated on the eastern side of the harbour, but nearly all the shipping has now been transferred to Apapa, on the western side, from where there is railway communication with the interior of the Colony. In 1921, contracts were let for the construction of an 1,800-ft. long blockwork wharf, in sloping bond, with the necessary railways, cranage, and sheds, sufficient to accommodate four or five vessels. The trade of the Colony is increasing to such an extent that a further 2,565-ft. of blockwork wall, with railways, sheds, etc., is now about to be added, together with a small 370-ft.-long lighter-wharf for general harbour purposes.

Kingston harbour, Jamaica, is a fine landlocked harbour but is rather handicapped by the limited depth of water in the entrance channel. Vessels berth alongside jetties which project into the harbour, in front of the business quarter of the town of Kingston, resulting in serious congestion in the streets. The Colonial Government are anxious to eliminate this by scrapping the jetties and constructing modern wharfage and a definite port area slightly to the westward. A scheme has been prepared but has not yet been sanctioned.

At Singapore, both lighterage and wharfage are used. The accent is on wharfage and most ocean-going vessels berth alongside the wharfs and in the large wet dock belonging to the Singapore Harbour Board. Considerable sampan traffic, however, is conducted in the Singapore River and in the eastern harbour area, which is protected by breakwaters. The greater portion of the trade of Singapore is conducted over wharfs and just before the 1939-45 war the Harbour Board carried out a 3,300-ft. extension of deep-water wharfage to meet the demands of increasing trade. This wharf-extension had eleven single-storey godowns, and a large area, about 500-ft. by 200-ft., is set apart for coal-storage.

The island of Barbados is a typical example of the lack of deep-water berthage. All ocean-going vessels have to anchor in Carlisle Bay, which is an open roadstead in front of Bridgetown; cargo has to be conveyed by lighters to and from the careenage—a small inlet or harbour, which can accommodate only lighters and small coasting vessels of light draught. The roadstead is on the south-western side of the island and so is protected from the north-east trade winds, but there is nearly always a swell which frequently interrupts lighterage work altogether, or confines it to one side of a ship. This is a case where deep-water berthage under break-

Kilindini, East Africa—showing cranes and double-storey sheds.

water protection is called for. As long ago as 1885, schemes of protected deep-water berthage were prepared, but financial difficulties have prevented any progress. Recently, the Colonial Government have called for the preparation of a scheme for deep-water berthage that will eliminate lighterage, which is less efficient and has become more costly in recent years.

(This paper would be incomplete without a reference to the wonderful lighterage traffic on the River Thames. The system employed in the London docks is well known. Lighterage can, in this case, be regarded more as a distributing agency over a vast area managed by the Port of London Authority than as a means of conveying goods to and from a vessel anchored in a harbour or roadstead, although a certain number of the smaller craft using the Thames are moored in the river. Most vessels trading in the Port of London, however, enter the docks or berth at riverside wharfs.)

The foregoing instances indicates the modern tendency to provide deep-water berthage. It is admitted, however, that, in the early days of most colonial harbours, financial difficulties have precluded the provision of suitable wharfs. The greatly increased trade developed by the Dominions and Colonies, from which increased revenues have been derived has, in many cases, enabled deep-water berthage to be provided, thus encouraging shipping to call for cargo. In this respect it is possible to draw an analogy with the provision of escalators to replace lifts at a tube station, which is said to enable, immediately, the number of passengers using the station to be doubled.

At this point, it is appropriate to make some general remarks about the design and materials to be used for the construction of wharfs. There are, in general, two main types of design, the solid structure and the openwork structure; the type adopted depends largely upon the foundation strata. There is no doubt that the solid blockwork, concrete-in-mass, or monolithic wall is the most durable and requires the minimum of maintenance; it proves to be cheaper in first cost, is easier to construct, and is less costly in maintenance charges, but the foundation strata disclosed by borings frequently preclude the solid type of design. In the openwork type of wharf or jetty there are numerous designs that can be adopted, such as cylinders, screw-piles, screw-cylinders, driven piles, etc., and the materials are costly and subject to deterioration—especially timber. The solid type should, if possible, be adopted in all cases, especially as it can withstand the occasional heavy shocks to which a wharf is liable when vessels are berthed carelessly. The openwork decked type is at a disadvantage with regard to the installation of the various service-mains required on a modern wharf (referred to later). The area required for wharf-sheds, if adjacent to the wharf-face, needs to be specially strengthened; this adds considerably to the cost. A further disadvantage of the openwork wharf or jetty is the necessity to provide for the heavy weights of wharf cranes and the point loads which occur during their operations. If cranes have to be installed, the consequent stiffening of the deck entails additional cost.

In general, it will be found that the solid-wall type is cheaper and, in the end, the more satisfactory.

Apron

The width of apron between the face of the wharf and the shed is important and depends upon whether or not cranage is provided; upon the nature of the cargo to be handled; and upon the method of operation of the port. Where ships use their own derricks and where there are no rail-tracks on the seaward side of the sheds, as at Singapore, a width of 40-ft. to 50-ft. is considered ample. On the other hand, with double-storey quay-sheds and portal cranes, a wider apron may be advisable; for instance, the new deep-water berths planned for Dar-es-Salaam are to have a width of 65-ft. in front of the sheds. With semi-portal cranes, however, this distance is not usually more than about 45-ft.; but, with such cranes, considerably more freedom of operation on the apron in front of the shed is obtained. Fig. 1 shows the lay-out of the aprons in a number of harbours. The main object of working on the apron should be to remove cargo as quickly as it is unloaded.

Colonial Harbours and Wharfs—continued

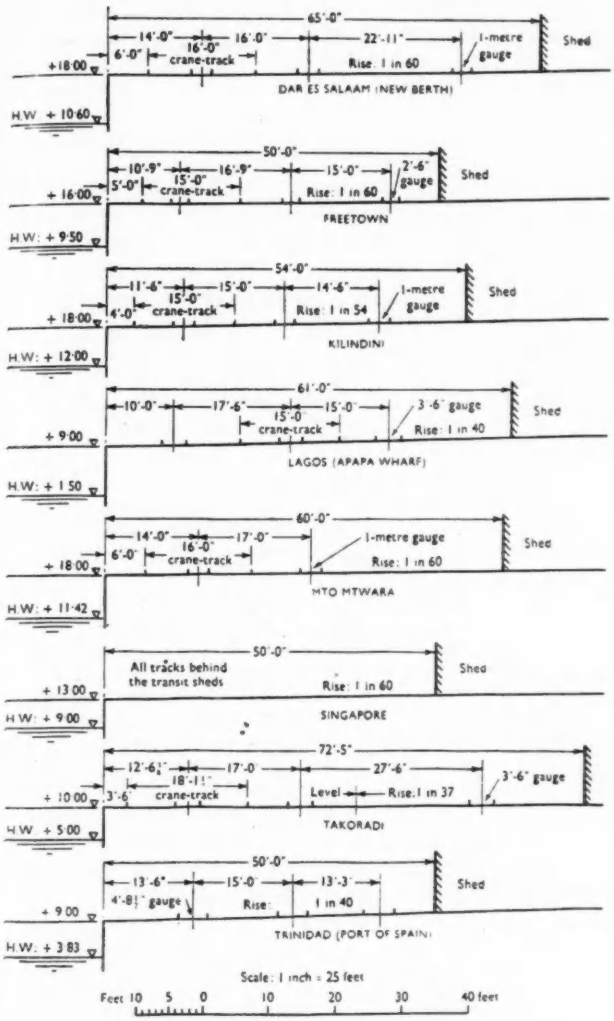


Fig. 1. Typical Cross-sections of Aprons.

It is of interest to note that, at the meeting of American Port Authorities in New York, in October, 1944, a very definite preference was expressed for single-storey sheds and an apron of not more than 30-ft. to 35-ft. in width. In fact, two-storey transit-sheds were recommended by none of the port representatives and only two of the stevedoring companies.

Sheds

There is, sometimes, disagreements as to the design of wharf-side shed to be adopted, and various points have to be considered before a decision can be reached. Most important is the load on the area occupied by the shed, which is generally on made ground, and considerable time should be allowed for completion of settlement. Single-storey sheds, 100-ft. to 150-ft. wide, with a minimum height to eaves of 17-ft., are the type generally erected, but double-storey sheds are sometimes advocated and the question then arises as to whether the large extra cost of providing what is equivalent to a high-level shed is worth while. It must be admitted that, in certain cases, two-storey or even three-storey sheds are justified where land is extremely valuable, as in the case of docks in large towns; if space is available, however, single-storey sheds usually fulfil all needs. It is sometimes claimed that one storey of a double-storey shed is required as a warehouse for goods awaiting shipment or vice versa, but Singapore is a good example of port working with single-storey sheds. The port is one of the greatest entrepôts in existence and probably more goods are warehoused, temporarily at these docks than anywhere else in the world. All wharf-side sheds at Singapore are single-storey steel-framed structures and no double-storey sheds are provided. The great weight of steel or reinforced-concrete double-storey sheds, with their stacked goods, usually necessitates piled foundations of a very substantial character and the following example of sheds for a colonial harbour recently tendered for by well-known firms of British contractors indicates the great difference in cost between single- and double-storey sheds.

A double-storey reinforced-concrete shed, 390-ft. long by 100-ft. wide, with piled foundations, costs, at the present time, £160,000; and of this the reinforced-concrete foundations cost not less than £16,000. A single-storey steel-framed shed of the same ground-floor area costs £64,000, or even less if a light type of construction is employed. Both of these sheds have their walls constructed of hollow concrete blocks. The initial cost of the single-storey shed can be reduced by using a cheaper form of construction which cannot apply to the double-storey shed since solid ground-floor walls are generally required for the latter.

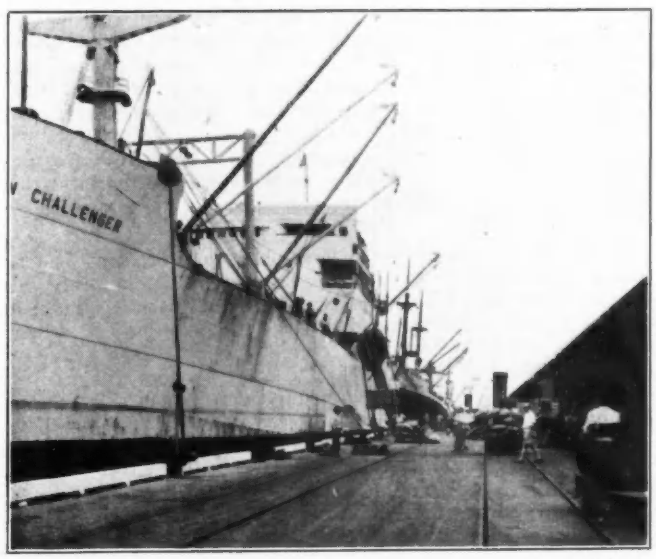
The advantages of double-storey sheds over single-storey sheds, if space is available for the latter, are not very apparent, since an elevated floor necessitates cranage or lifts for storing and removing goods and entails the use of more power and consequential increased costs. Furthermore, single-storey sheds do not require such heavy piled foundations, because simple concrete bases for the stanchions and walls are generally found to be satisfactory.

The Author suggests that, if space permits, both transit sheds and warehouses should be single-storeyed, the former being placed near the quay and the latter behind them.

Before deciding upon the required capacity of a shed, it is necessary to know the percentage of cargo to be stored, the period of storage, and the average tonnage passing over the berth during this period. As a rule, the larger the vessel the greater is the amount of cargo that has to be dealt with per lineal foot of berth. For computing the accommodation required, it is reasonable to allow 80 cubic feet for each ton of general cargo to be stored. This figure allows for the provision of passages and for access to the stored cargo.

The sheds should run the full length of the berth, allowing room for rail and vehicle approaches to the apron, and should be fitted with large sliding doors with openings at least 12-ft. wide at 50-ft.-60-ft. intervals or, say, eight to ten per berth. The doors on the sea front should all be high enough to permit the entry of mobile cranes into the shed.

When planning the shedding required in a port, accommodation for the garaging of mobile equipment and the storage of landing



Port of Spain, Trinidad—unloading by ships' derricks and fork-lift trucks to single-storey sheds.

Colonial Harbours and Wharfs—continued

Interior of a single-span shed—Singapore.

gear such as pallets, trays, slings, etc., should be borne in mind if valuable floor space in transit sheds and warehouses is not to be taken up. If such equipment is properly housed, the risk of fire is much reduced.

Cranage

The type of wharf crane to be installed, its lifting capacity, and the distance from face of coping, etc., should all be considered. The type of crane usually adopted is the electric portal level-luffing crane of 3—7 tons lifting capacity, having a radius of operation of about 65-ft.

The following speeds of operation are usually specified :—

Hoisting : from 200-ft. per minute for 3-ton cranes to 85-ft. per minute for 7-ton cranes.

Luffing : from 80-ft. to 120-ft. per minute.

Slewing : 1½ revolutions per minute.

To ensure the quick discharge of cargo, four units of light lift-capacity are usually allotted to one large steamer, with an occasional 7-ton crane for slightly heavier lifts. Portal cranes are the handiest and the distance of the front crane-rail from the face of the coping is usually 6-ft. and should not be less, since space is required to clear the overhanging promenade-decks and projecting bridge-wings with which modern vessels are fitted. In some cases, semi-portal cranes are used, but this entails having the rear leg of the crane on the front wall of the shed and also requires the provision of additional stiffness in the front wall and means for bridging the space between sheds.

The front rail of a portal crane can be supported on the superstructure of the wall, but the foundations for upholding the back leg, which is usually on made ground, require consideration. Piled support can be used but a more common foundation is a flexible raft of rubble and concrete, which, however, requires watching and maintenance until all settlement of the track and risk of consequent injury to the framework of a crane ceases. Unless this supervision and maintenance are carried out, serious damage to a costly piece of plant may occur.

The necessity of supplying a heavy-lift crane of, say, 25 tons capacity, especially of the travelling portal type, is doubtful. This type entails the provision of a very substantial back-leg track, in which settlement must be avoided, since the point-load on a back wheel is extremely heavy. The foundations for a fixed heavy-lift crane are easier and less expensive to construct, but this involves moving the vessel to the crane—a procedure which ship masters dislike intensely. On the other hand, the transit of a heavy wharf-crane to the ship interferes with the organization of the wharf, because the light cranes have to be moved out of the way. Nowadays, however, vessels are often equipped with their own gear for handling heavy lifts.

In most large ports, a floating crane is available and this is certainly a more useful piece of plant than a heavy crane on a wharf, since it can be used in every part of the harbour and can deal with moorings, anchors, etc., and attend vessels moored in the stream. The initial cost of such a crane is, however, high and it requires attention and careful maintenance.

The question of A.C. or D.C. electricity-supply for cranes and lifting appliances generally has not reached finality. In some ports there is a tendency towards the use of D.C. but the majority of colonial ports work on A.C.-supply.

Apparently the work of these ports does not seem to warrant the expense of equipment for converting the supply for cranes to direct current, in order to take advantage of the flexibility of D.C. motors and control-gear.

Features and Fittings

The height of the quay above high-water-level should be not less than 6-ft. when the range of springs tides is about 9-ft. With a smaller range of tide, this height should be increased to about 10-ft. These levels are frequently determined by the height of existing works of a similar type in the same locality.

To prevent damage to the screws of twin-screw vessels, it is advisable that the top course of blocks and also the superstructure of a wall should be corbelled out 18-in. or even 2-ft., which, with the fendering, helps to prevent damage to propellers. Large floating fenders can be used in the case of a solid wall for the same purpose.

Fendering on the face of a wharf is very desirable, especially in the case of the openwork type of wharf or jetty, since its assists in absorbing the impact and acts as a cushion when a vessel is berthing. The fenders are usually of timber with renewable face-pieces, fixed securely to the wharf-face; floating fenders or camels may be used in the case of solid walls. Vertical suspended fenders can be used on openwork wharfs, and one of the best type is a bundle of hop-poles, about 18-in. in diameter, firmly bound with wire-rope lashings, which makes a very resilient type of fender.

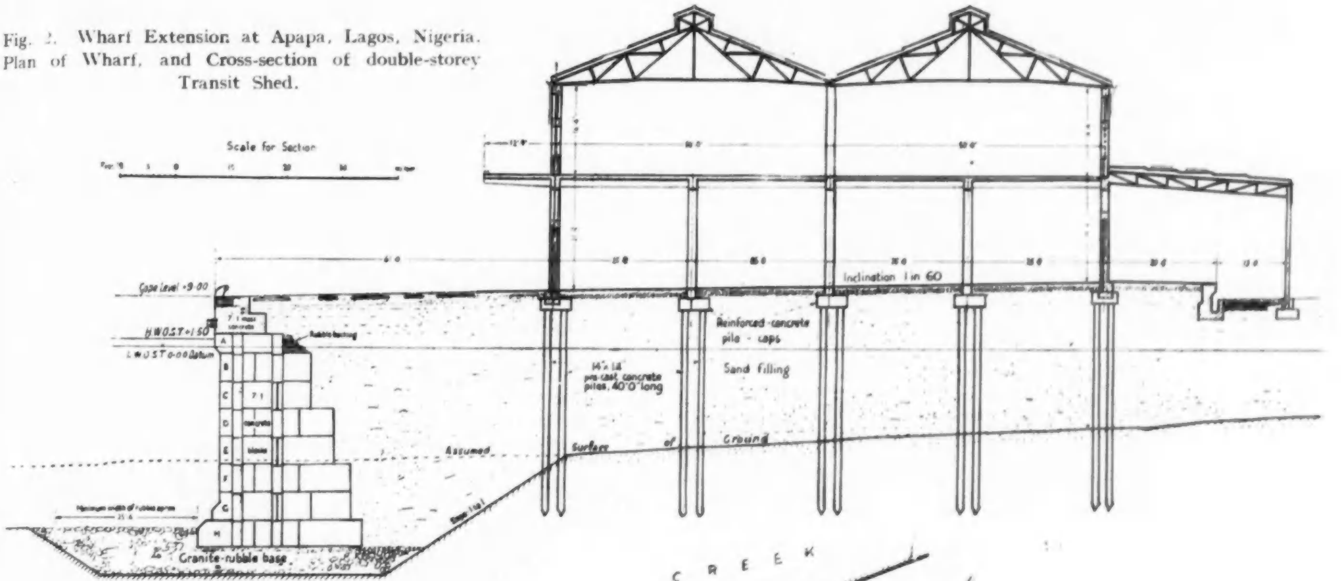
In the case of wharfs constructed on piles, whether the piles are of reinforced concrete or steel, it is desirable to introduce some form of spring or cushion behind the fendering to absorb the shock caused by a vessel berthing.

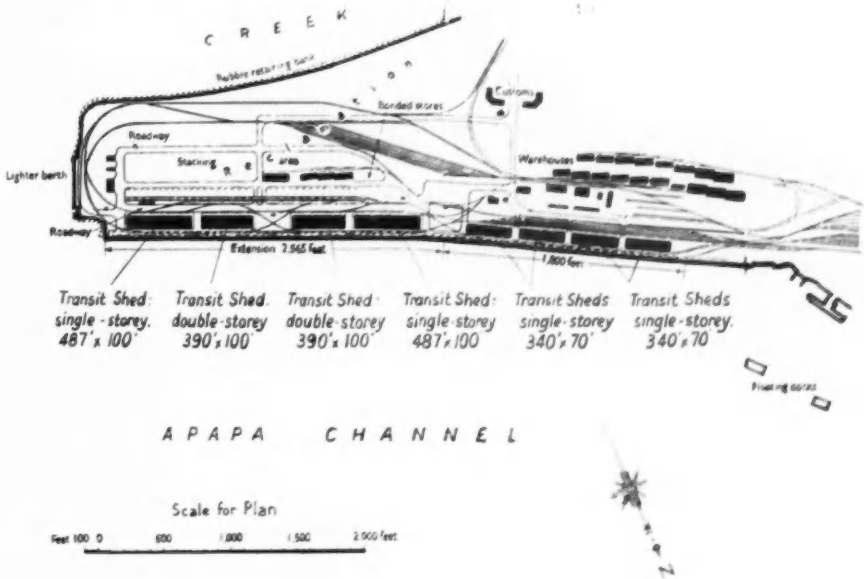
There is some diversity of opinion as to the types of bollard to be provided. Cope-hook-bollards are essential and should be spaced at 50-70-ft. centres but certainly at not more than 70-ft. centres. They should be of cast steel and have their top front faces well rounded, because cases have occurred where the flare of ships' bows has been staved in by faulty berthing and by the vessel striking the top of an angular bollard. Mushroom- or pillar-type bollards should be provided and are most desirable where large

West Wharf, Singapore—showing single-storey shed and unloading by ships' derricks, one solitary crane in the distance.

Colonial Harbours and Wharfs—continued

Fig. 2. Wharf Extension at Apapa, Lagos, Nigeria. Plan of Wharf, and Cross-section of double-storey Transit Shed.





vessels with a lot of top hamper, especially tankers, are berthed. It is seldom realised that the bow of a large unladen tanker rises 50-ft. to 55-ft. out of the water and that attachments to cope bollards give insufficient lead. Whereever possible, therefore, pillar-bollards should be fixed 30-ft. to 40-ft. back from the cope edge. Dock managers do not favour these because the mooring-ropes, unless properly tended, interfere with railway and other traffic on the quay. They should, nevertheless, be provided.

Oil Berths

In all harbours where oil bunkering and storage occurs, a separate berth for tankers is usually provided; and this should be away from the wharfs where cargoes are handled, especially if petrol is in evidence.

Many port authorities have found it to be an advantage to retain possession of such berths; otherwise an authority may be involved in the payment of heavy compensation when future extensions of the harbour are required. Oil-storage and oil-handling facilities should be available to any would-be importer, so not only should oil-berthage be available for common use but also, in cases where storage-areas and tank-farms are remote from the harbour-area, common-user pipe-lines and booster pumping-stations should be operated by the harbour authority as part of the port facilities.

Modern conditions make it essential to provide for oil-bunkering of vessels alongside the wharfs and the provision of pipe-lines and suitably sited offtake points for both furnace and diesel oils is required; in addition, it may be necessary, at some harbours, for special berths to be equipped for the bulk-loading by pipe-line of molasses, coconut and palm oils, and rubber latex.

The provision of these service mains, together with those for fresh water, fire prevention, electric power and light, telephone (with their necessary ancillary appliances), hydrants, and connexions—which, as far as possible, should be kept clear of rails, roadways, crane-tracks, and the bollards on the quay—complicate the arrangement of the superstructure of a modern quay-wall.

Careful consideration must also be given to such matters as the siting of fresh-water hydrants, so that the hoses do not foul crane- or rail-tracks; the placing of fire hydrants so that, in the event of a fire, they will not be unusable; the positioning of telephone plug points; safeguards against oil-spillage; and provision for emptying flexible branch-pipes and returning contents to the main pipe-line.

Borings

Before describing works under construction, attention should be drawn to the care which should be taken in the selection of suitable sites for such works and, in particular, to the proving of the ground by means of boring.

Colonial Harbours and Wharfs—continued

Boring-records frequently give too little information about the hardness, density, or otherwise of the strata passed through and disclosed by the borings. Descriptions such as "clay," "sandy clay," "sand," and other short non-informative descriptions of strata should be amplified in terms of hardness, density, etc. Information about the type or name of the boring tool used in each case, as well as the time taken to pass through a certain depth of strata, would make it easier to form an opinion as to the suitability of the material for a foundation and as to the nature of the materials to be removed by excavation or dredging. This matter is mentioned because borings can be misleading and frequently unreliable, and the value of the information obtained from them is not enhanced by short and imperfect description of the strata.

The following are short descriptions of some works at colonial harbours.

Lagos, Nigeria

The extension of the Apapa wharfage at Lagos, Nigeria, is a good example of the design for a quay to meet modern requirements and has been evolved from the experience gained from the working of the existing wharf at Apapa. The extension (see Fig. 2) consists of a 2,565-ft.-long concrete blockwork wall, built in sloping bond, the heaviest block weighing 15 tons. The slices of blocks are keyed together by two tongues and grooves, extending for the full height of the blockwork. The foundations are on sand, a trench being dredged therein to a depth of 40-ft. 6-in. below low-water-level and the wall founded on 5-ft. of granite rubble sealed with a layer of crushed stone. The ultimate depth alongside will be 32-ft. at low-water spring tides but, in the meantime, the sandbank in front of the wharf is to be dredged to give a depth of 26-ft. It has been found that current-action alongside the existing wharf maintains a depth of water of more than 26-ft. at L.W.S.T. An apron of granite with its surface-level at —32.00 extends for a distance of 25-ft. from the toe of the wall, in order to counteract scour alongside and the action of ships' propellers.

The wall is constructed to a slight batter of 6-in. in its total height, so that any squeeze at the toe is taken up and the face becomes more vertical. The superstructure of the wall is of 7 : 1 mass concrete with vertical construction-joints over every third joint in the slices of blockwork. The latter will provide for any slight settlement in the blockwork and minimize the risk of unsightly cracks in the face of the wall.

The range of tide at springs is only 18-in. and the level of the quay surface is 9-ft. above low-water-level, to coincide with the existing wharf. One horizontal fender of colonial hard-wood is fitted in a groove, well above high-water-level, where it will be immune from the risk of destruction by marine pests. The coping is of moulded concrete and its surface is treated with carborundum grains, to give a non-skid surface. Cast-steel cope-bollards are spaced at 65-ft. centres and ladders are fitted at intervals of about 195-ft.

Behind the wall, there will be an extensive area of reclamation, of 1,000-ft. minimum width. Sand from the excavations and other sources, such as dredging in the harbour and adjacent creeks, will be pumped in. The back and end of the reclamation-area, where not protected by the lighter berth, will be formed by a rubble bank, and a transverse bank of rubble will divide the reclamation into two areas. The inner area will be reclaimed first, in order that a portion of the wharf may be brought into use as soon as possible.

A lighter-berth, 370-ft. long and 16-ft. deep at low water, is provided at the outer end of the reclamation-area to accommodate light craft which navigate and trade along the several inland creeks communicating with the main harbour.

On the wharf itself, it is proposed to build four sheds : one double-storey shed, 487-ft. 6-in. by 100-ft. ; two double-storey sheds, each 390-ft. by 100-ft.; and a single-storey shed, 487-ft. 6-in. by 100-ft. On the reclamation-area, three bonded stores, a King's warehouse, 200-ft. by 50-ft., together with stores for dangerous goods, are to be erected, and customs, railway, and shipping-offices are to be provided. In addition to three lines of railway in front of the sheds and one line immediately behind them, extensive siding-accommodation and a grid are to be laid. Road-access will be available along the rear of the sheds, and also to areas earmarked for stacking bulk cargoes and heavy goods and to sites set apart for future development.

At the rear of each wharf-side shed, a wide railway-platform is provided, which, together with the railway-line, is protected from the weather by a light roof of 33-ft. span, the outer end being supported on mild-steel columns.

The foundations of the double-storey sheds are carried on reinforced-concrete piles, generally in groups of three, each pile being driven to a set capable of withstanding a load of 50 tons. The ground floors will be formed of concrete having a granolithic finish and will be laid on a base of granite hard-core, well consolidated and blinded. The shed walls are built of pre-cast-concrete hollow

Lagos, Nigeria—showing cranes and double-storey sheds.

blocks and the roof consists of asbestos-cement tiles with roof glazing. The upper floor of the larger double-storey shed has been set apart for passenger-traffic. It will contain a large hall for customs examination and compartments for mails, parcels examination, post office, port medical officer, restaurant, waiting rooms, etc. These offices will be served by lifts from the ground floor in addition to a staircase at each end of the shed.

The installations provided for this wharf-extension are typical of what is required for a modern quay with terminal railway communication dealing with a large export trade in addition to the imports required for the Colony. The question of cranage has not yet been decided, but provision has been made for allowing the existing heavy-lift 25-ton crane to traverse the upstream end of the new wharf for a distance of about 150-ft. and crane-track is being provided for this purpose.

(To be continued)

The Design of Quay Cranes

Some Basic Factors Affecting Proportions

By VALDEMAR RANG

Efficient port operation to-day is dependent to an increasing extent upon mechanisation. For the mechanical handling of cargo, when loading or unloading ships, most European and many overseas ports are using quay cranes which, though usually made to order, bear quite a few resemblances. Although conditions vary considerably in different ports, there seems to be some requirements in a quay crane of a rather general nature.

The original hydraulic or steam-driven cranes have mostly been substituted by electrically-operated ones, which gradually have been brought to a high degree of perfection, especially since the introduction of the level luffing movement which enables them to work so smoothly as to give an impression of almost being living things.

Proportioning the outline of a quay crane calls for the determination of a few basic facts and figures only, and is intimately connected with the lay-out of the quay crane area. The fundamental factors with regard to the side-view of a crane are, for the superstructure, the location of the centre of rotation, and the extreme positions of the hook as to outreach and highest lift. The supporting portal, or full- or semi-portal type has to be dimensioned with respect to overall dimensions, as well as to clear height and width inside the portal.

A comprehensive study of the lay-out of quays and their equipment, i.e. warehouses, railway tracks, lanes for motor traffic as well as cranes, was published in the Dock and Harbour Authority for January 1951, in an article written by Major Herman Jansson of Stockholm. That article, which aroused a great deal of interest, is based on conditions prevailing in most Swedish ports, where both railway and motor traffic is allowed on the quay. Similar conditions also exist in some British and some other West European ports. The accumulation of different transporting units on the quay has increased the demand for space and there are quays, built and proposed, with 100 or 150-ft. width.

When the main dimensions of a quay crane are to be determined, it is first of all necessary to draw and study a cross-section of the quay, showing a large ship with perhaps one or two lighters on the outside, the position and number of railway tracks as well as the front of the warehouse (see Fig. 1).

The placing of the centre of rotation and the determining of the out-reach of the crane requires a study not only of the profile, but

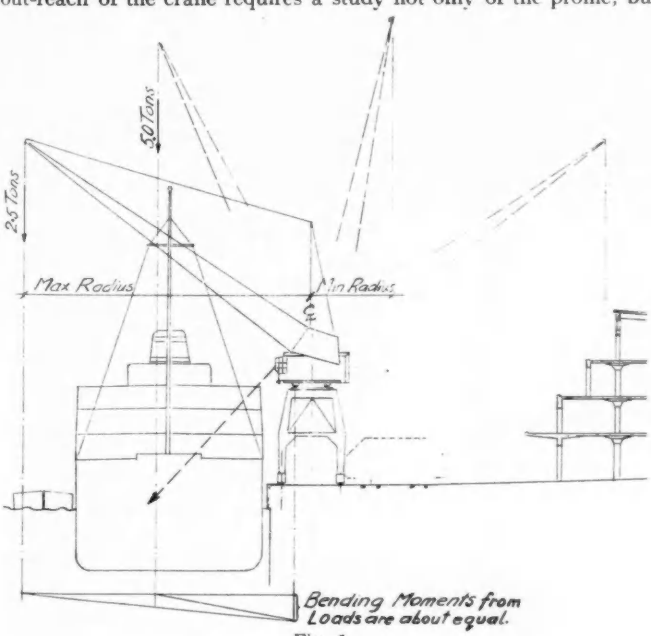


Fig. 1.

Fig. 2.

preferably also of the plan of the quay, as the traffic problems have to be solved for the quay as a unit.

The revolving centre of a crane can be placed quite differently depending on requirements—compare Figs. 1 and 3. The maximum radius usually varies between 70-ft. and 100-ft., but there are cranes with a still larger out-reach. In the port of Rotterdam for example, there are several cranes with a radius of 120-ft.

The position of the driver's cabin is important for the safe and easy manœuvring of the crane. The driver must have the best possible view through the front window, and therefore the cabin should be placed high above the quay and also far out from the rotation axis, but not so far that the load might happen to smash the window pane. Neither should the cabin be so far out that it might collide with the ship. The same applies to the counterweight etc. in the back of the crane.

The portal, movable along a track parallel to the quay, can be designed in many different ways. Usually British built crane portals are rather high and of a moderate span, and, as a rule, they are full portals. This design leaves a maximum free working

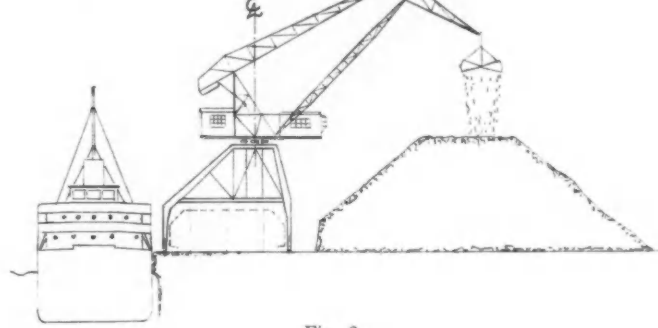


Fig. 3.

Design of Quay Cranes—continued

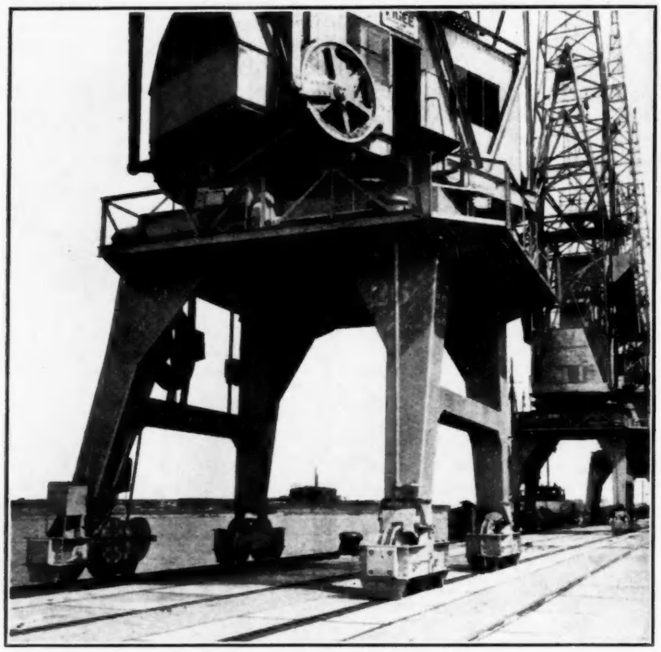


Fig. 4.

space around the crane and there now seems to be a tendency by designers towards rather narrow and high gantries of the full portal type.

On a modern quay, 100-ft. or more wide, a semi-portal crane could not possibly span the whole width of the quay, without forming a serious obstacle for working, and semi-portals with a shorter span supported on an elevated land-side track are also subjected to disadvantages of a similar kind.

Fig. 1 shows a crane designed according to the principles mentioned above, Fig. 2 shows a modern level luffing crane lifting 2.5 tons at 100-ft. and 5 tons at 50-ft. radius, and Fig. 3 shows a crane designed to reach as far from the water as possible. Fig. 4 is an illustration of a welded crane portal of elegant design.

The outer portal rail has to be placed far enough from the quay in order to lessen the risk of collision between ships and cranes. As the ship of to-day has quite a protruding stern and bow, these risks have increased.

In order to prevent the back parts of two cranes, standing close together, from colliding when turning, the portals may be made sufficiently wide at their bases, so that several cranes can stand with buffers in touch and work without clashing (see Fig. 5). Usually the portals are built without bracing between their legs

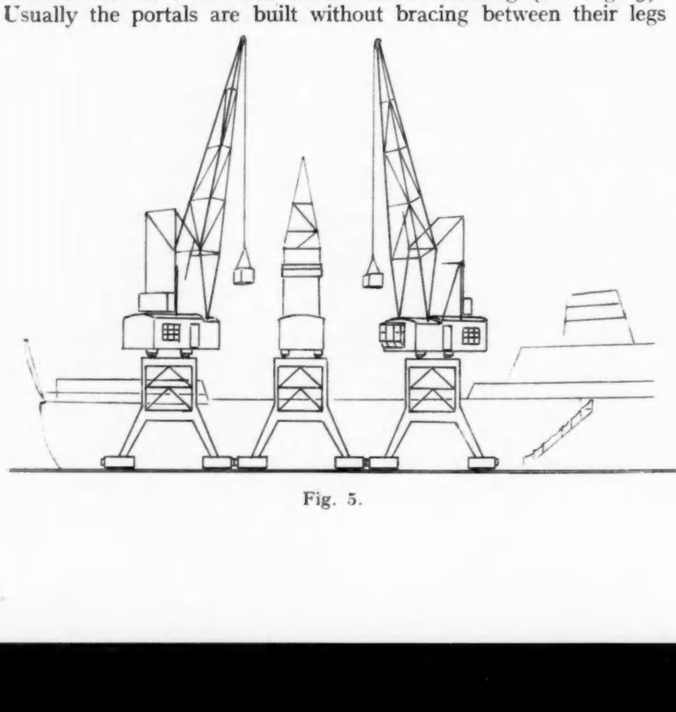


Fig. 5.

in order to provide free passage underneath in both directions. Thus there will be no screening off of any part of the quay.

As far back as 1910, cranes were built in Britain incorporating the level luffing system. On the Continent however this system was not generally accepted until much later. Now there are a great many different level luffing systems in use, and it seems that most large crane building firms have specialised in some such system, which gives a quite typical appearance to their cranes.

The level luffing principle implies that the load can be moved radially along a horizontal path and all points within a broad circular ring can be reached. Slewing, derricking and hoisting or lowering can be done simultaneously.

On the Continent, and in Sweden, the double hinge system for cranes is widely used (see Fig. 3). It is so arranged that the crane hook follows an almost horizontal path during the derricking movement and the length of the wire is not affected thereby.

This design has some disadvantages, such as the somewhat heavy weight of the arm system, which also exposes a large area to wind pressure. A certain lack of stiffness laterally can be noticed.

Lately, the design with a single boom has been gaining ground rapidly. The length of the wire has to be regulated as the boom is raised or lowered in order to provide a horizontal path for the load and this is achieved automatically by means of some more or less complicated mechanism.

The straight single boom usually is quite long, giving the crane wire a long free length, especially on a short out-reach. This is said to be an advantage as the pendulum movement is slowed down and it is therefore easy to follow the load with the light boom and to eliminate the oscillation of the load.

The lifting power of quay cranes for general cargo, two or three tons on the maximum out-reach, frequently is increased to five tons on a shorter radius so as to give an unchanged overturning movement. The counter-weight is so calculated that the centre of gravity for the superstructure does not fall outside the bearing wheels on top of the portal.

Port Labour Problems

Lord Crook's Speech at Middlesbrough

Early last month, Lord Crook, the new chairman of the National Dock Labour Board, visited Tees-side to inspect the docks and riverside facilities for shipping, and in a speech to the River Tees Council of Port Labour Employers, he stated that his one ambition was to get the dock labour organisation as far away from bureaucracy and the filling in of forms as possible. He said it was a pleasure to him to have the opportunity of playing a part in finding a solution to what he felt to be one of the countrys great sociological problems. When recent developments came to be included in the nation's industrial history, there would be written large in it the story of the experiment made by the creation of the Dock Labour Board. As one who had seen something of the early struggles of dockers, he felt that the inspiration of the National Dock Labour scheme would go down in history.

It might be that many workers had still to be convinced that they were living in a new era and that that great traditional loyalty which had been theirs throughout this country must now be mobilised and used in the country as a whole. Many might still find it difficult to understand that employers were not ogres to be afraid of, but were people who were trying to work in an atmosphere of understanding, co-operation and goodwill. The dock labour scheme was teaching the industry how easy it was for both sides to get together in the common interest, and he liked to think there had grown up in recent years an understanding second to none.

In conclusion, Lord Crook said he was satisfied there was no justification—although others might try to exploit the dockers' loyalty—for the fear that employers were trying to put one over the dockers. Employers, like union representatives, were striving hard to ensure that the scheme worked to produce a peace and understanding in the industry which could not have been visualised 50 or even 20 years ago.

Tidal Phenomena

With Special reference to Southampton and Poole

By F. H. W. GREEN.

KNOWLEDGE of the tides has increased greatly in recent years, but much of this knowledge is still imperfectly disseminated outside specialist circles, and statements of varying degrees of inaccuracy regarding tides still appear on otherwise sound texts. An important reason for this lies in the fact that although much has been discovered by the tidal mathematicians, there are still large gaps in our knowledge, and it requires considerable skill, when presenting the known facts in non-mathematical language, to avoid the appearance of bridging these at present unbridged gaps.

Neither of the usual approaches to tidal study has led to a terminology which can, as it stands, be used for wholly satisfying descriptive purposes. The seaman's approach is usually one which uses terms and even concepts that are out of date as compared with those of the mathematicians and astronomers, even though the Admiralty Hydrographic Department and the Liverpool Tidal Institute try to make their terminology and methods familiar to the navigator. A further complication is that in north-west European languages the only familiar terms for tidal phenomena are those describing the more obvious features of the particular tides experienced in the fringing seas of the north-eastern Atlantic. In everyday English, such words as **spring tides** and **neap tides, ebb and flow,** are almost all we have. Nautical terms like "High Water, Full and Change" (H.W., F. & C.), and a number of local dialect words, such as one finds, for example, to describe features of the unusual tides of the Channel coast of England, add to our tidal vocabulary. Beyond this we have to turn to a scientific—or in some cases pseudo-scientific—terminology, which is pitted with imperfect synonyms. This brings in such terms as **anomalistic tides, semi-diurnal tides, apogee tides,** and so on.

The movements of the heavenly bodies which are responsible for the **tide-producing forces** have long been fairly well understood, and we know that it is necessary only to consider the relative positions in the heavens of the earth, sun and moon. The gravitational effect of the planets can be discounted. With this knowledge it is possible to state what would be the tidal movements on an earth which had a uniform cover of water. That is one end of the story. At the other end of it we have a large series of records of tidal rise and fall, ebb and flow, for a great many places on the sea coasts of the world, though we still have not enough of these, nor have we found how to measure satisfactorily the relatively small, but very significant, tidal movements in the open ocean. How are we able to link our knowledge of the astronomical factors and their effects on a uniform hydrosphere with those observed tidal movements on the coasts of a much interrupted and very irregular hydrosphere?

Any record of the rise and fall plotted on a graph can be subjected to harmonic analysis, and an irregular curve can always be shown to be a combination of a more or less large number of simple sine curves which can be plotted on ordinary square ruled graphs. Our present knowledge is such that for all tidal observations the great majority of these simple sine curves can be labelled, and they are recognisable from one tidal graph to another. Moreover each one can be related to a particular **tide-producing** force, such a single force being itself the result of resolving into a series of simple sine curves the complicated curve expressing the combined effects of the forces exerted on the earth. The various labelled curves are normally recognised by their period, or wave-length. The amplitude of each is subject to variation from one place to another, and their phase relationships with each other are subject to similar variation.

The labelled curves representing the various constituents of the **tide-producing forces** are as follows: M_2 is the **principal lunar semi-diurnal constituent,** with a speed measured in degrees per mean solar hour of 28.984. This figure is for convenience referred to as the **speed number.** Deriving from the fact that the moon's orbit is elliptical, we have N_2 and L_2, with speed numbers of 28.440 and 29.528 respectively. The principal effect of the moon's declination is shown by the constituent K_2, with a speed number 30.082.

Similar constituents have reference to the solar semi-diurnal tide-producing forces. S_2 corresponds to M_2 and has a speed number of 30.000. T_2, with a speed number of 29.959, corresponds with N_2. The chief constituent due to changes in declination of the sun has the same speed number as that for the moon; K_2 is therefore treated as a luni-solar constituent.

Turning to the diurnal constituents, we find K_1 and O_1, with speed numbers respectively of 15.041 and 13.943, which both embody the effects of declination. Three other constituents are introduced to cover the diurnal effects of the moon's parallax. They have speed numbers of 13.399, 14.492 and 15.585 respectively.

The amplitude of K_1 is increased by the fact that it has exactly the same speed number for the sun as for the moon. So, like K_2, it is a luni-solar constituent. Another diurnal constituent, P_1, is also introduced by the solar declination factor. This has a speed number of 14.959.

There are nine harmonic tidal constituents which are commonly quoted, four of them being the semi-diurnal, M_2, S_2, N_2 and K_2, and three being the diurnal, K_1, O_1 and P_1. The remaining two, M_4 and MS_4, are so-called shallow-water constituents, and to understand them some further considerations must be introduced. It is known that tides are essentially stationary wave oscillations, such as are produced in a bath when tilted, and are not travelling waves. Any body of water contained within solid boundaries has a natural period of stationary wave oscillation when it responds to any disturbing influence. Since all bodies of sea and ocean water on the earth's surface are contained within very irregular boundaries, it is not difficult to see that their response to the tide-producing forces will be very complicated—too complicated, in fact, to deduce from first principles. Herein lies the unbridged gap in our knowledge. The reaction of the oceanic bodies of water to the main diurnal and semi-diurnal constituents is, however, sufficiently well marked for the gap between theory and observation to be at least partially bridged. It is approximately known what are the diurnal and semi-diurnal oscillatory systems in the major oceans and what peripheral seas are so shaped that they will oscillate in harmony with the oscillations of the ocean adjoining them.

In shallow waters, however, oscillations are often set up which have periods which are submultiples of the major diurnal or semi-diurnal lengths. It is as though the bath had a shallow rim; tilting such a bath can readily be shown to produce similar complications on a small scale. The amplitude of these minor oscillations is usually very small when compared with the more important harmonic constituents, but locally they do become important, for they can produce the phenomena of so-called **double high waters** and **double low waters,** as exemplified in the central part of the English Channel.

A comparison of the relative amplitudes of the different constituents can be obtained from Table II.

There are also harmonic tidal constituents with much longer periods, notably one of 18.61 years, during which period the orbit of the moon follows a regular cycle of change, particularly in the amount of declination. All factors depending on the latter are thus subject to variations on this account.

In order to effect the stationary wave oscillation, there must be horizontal components in the movement of the waters, and these give rise to **tidal streams.** If one makes use again of the analogy

Tidal Phenomena—continued

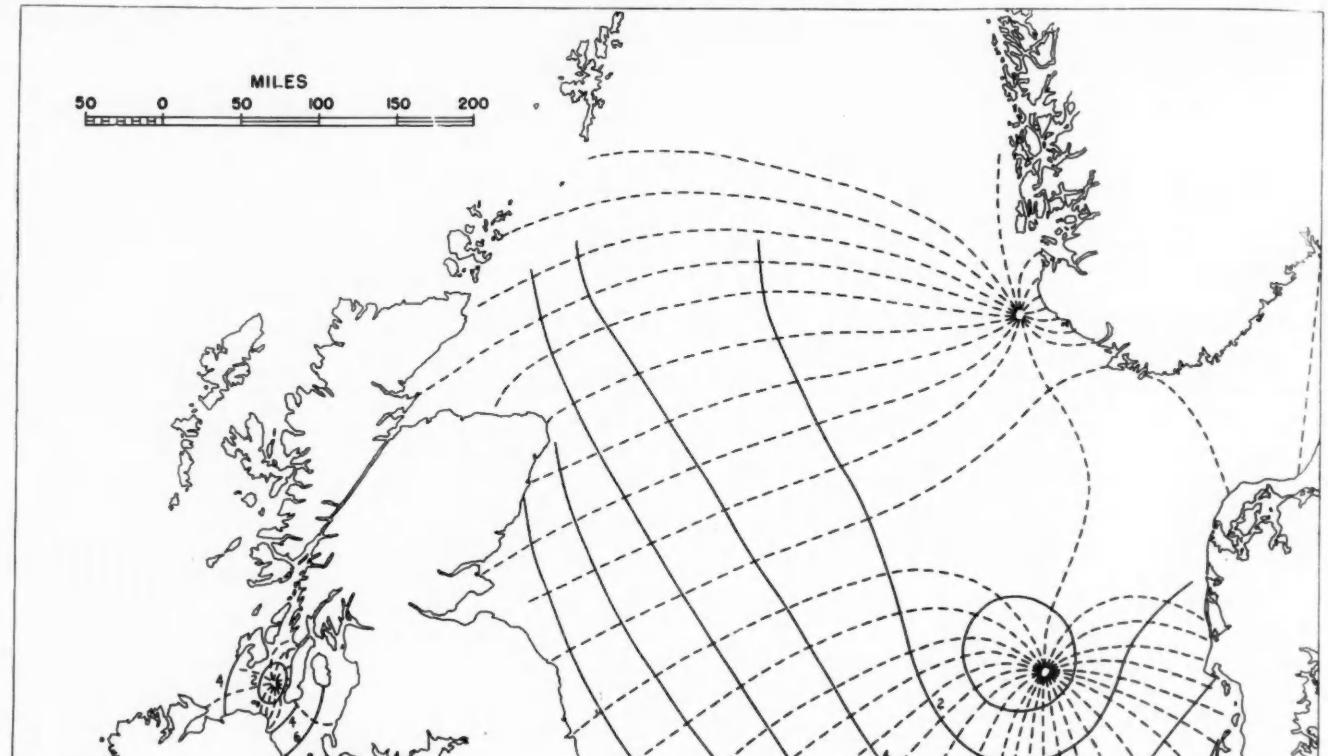


Fig. 1. Co-range lines of main tidal constituent M_2; the figures indicate the average range in feet. The pecked lines are co-tidal lines, indicating points at which times of high water are equal. (Based on British Admiralty Chart No. 5058, with the permission of the Controller of H.M. Stationery Office and of the Hydrographer of the Navy.)

of tilting the shallow-brimmed bath, it can readily be appreciated that these horizontal tidal streams will be more noticeable in shallow water, such as is found in estuaries or between islands.

The tides of the North Sea, Irish Sea, and English Channel have been investigated in some detail by the staff of the Liverpool Tidal Institute, and a chart is published showing the ranges in these waters of the main semi-diurnal constituent M_2. It is reproduced herewith (Fig. 1). The North Sea appears to behave with respect to this constituent as though it consisted of three tanks, in each of which was maintained a stationary wave oscillation such that high water at the edge of one corresponded with high water at the adjoining edge of its neighbour. It is, of course, clear that equilibrium could not otherwise be maintained. If a tank were tilted only in one direction, there would ideally be a nodal line across the centre where the amount of tidal rise and fall was nil. Owing to factors introduced mainly by the rotation of the earth, but also to the fact that the natural "tanks" are very irregular in shape, the nodal line becomes a point. Such a point of no rise and fall is called an **amphidrome,** and the tidal streams appear to circulate round it. In the North Sea there are three

Tidal Phenomena—*continued*

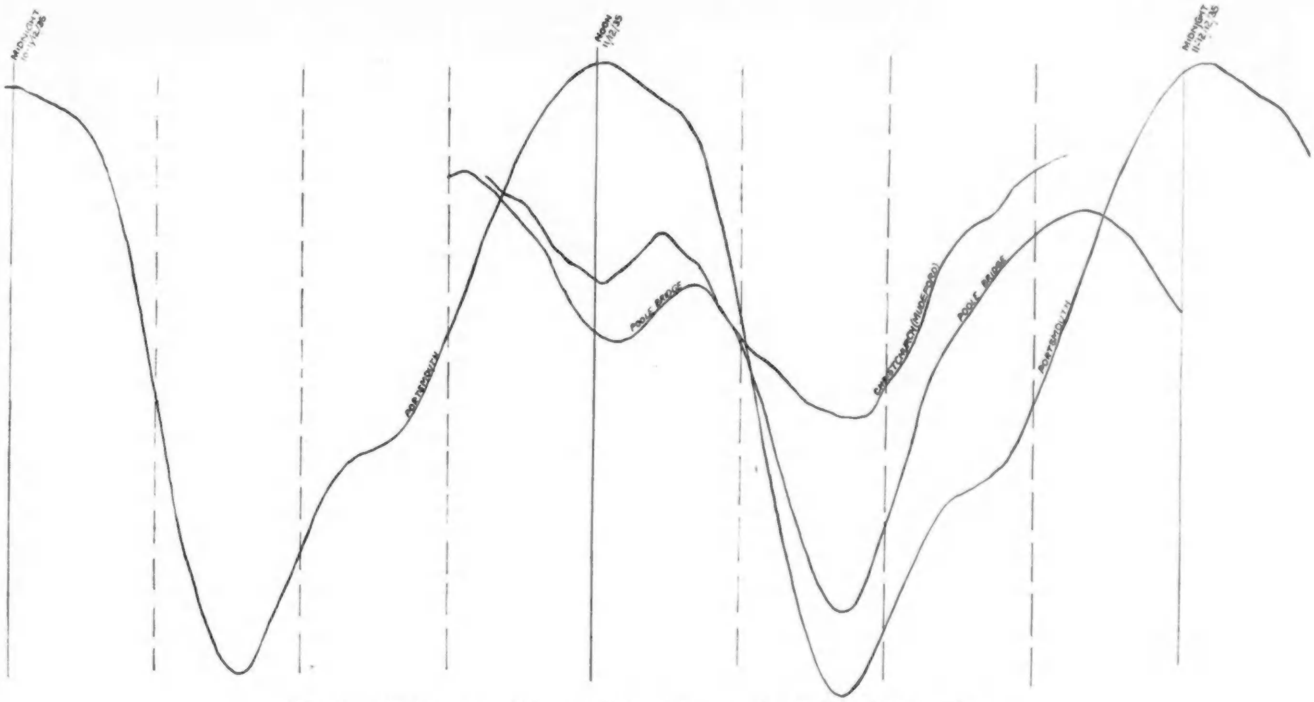


Fig. 2. Simultaneous Tides recorded at Portsmouth, Poole and Christchurch.

amphidromes; in the English Channel there is no nodal point; but near the Hampshire and Dorset coasts the tidal range is at a minimum, and it may be supposed that if the Channel were wider there might be an amphidrome in the neighbourhood of what is in fact Wiltshire. It is near such amphidromes calculated in respect to the tidal constituent M_2 that we might reasonably expect to observe the effects of the minor constituents which elsewhere would be hidden by the large effects of M_2. Fig. 2 shows a selection of actually recorded tides for identical periods at Portsmouth, Poole and Christchurch.

In order to make clear some of the points alluded to in general terms above, the following paragraphs set out some of the features of the tides of Southampton Water, and their practical significance.

Table I is a statement of the main tidal features of the port of Southampton in the non-harmonic terms, which were the sole terms in use until a few years ago. The second two columns in this table refer to the interval of time after the moon's transit, at "Full and Change" (i.e. full moon and new moon), when high water and low water respectively occur. Since there are two high waters at Southampton, the figures in the first column are duplicated; i.e. if there is one maximum of tidal height at 10h. 55m., there is another at 12h. 57m. It should be noticed that in the seas of north-western Europe generally, spring tides do not occur actually at Full and Change, but approximately three days later. Consequently at springs, high water and low water occur about two and a half hours later than the times shown in these columns. This means that at springs, the (first) high waters are at approximately one o'clock in the morning and half past one in the afternoon; the low waters are at about half past six in the morning and seven in the evening. This fact is of some practical importance. The most likely time for a vessel to go aground is in the early morning, when the very lowest tides occur. As explained below, the morning tides at springs are commonly slightly lower than the evening ones. Moreover, liners are more often timed to arrive in early morning than in the evening. If such an unfortunate mishap should occur, the whole period of daylight, including the high tide soon after noon, is available for the sometimes harassing process of re-floating.

Certain other information can also be read from this table. For example, one learns that at Calshot, at the entrance to Southampton Water, the low water and both high waters occur five minutes later than at the Town Quay, Southampton. On the other hand, at Redbridge and Woodmill, near the heads of the Test and Itchen estuaries respectively, the tides tend to occur earlier. What in fact happens is that, as indicated in the remaining columns in the table, the tidal range is greater; at high water, for example, the tide continues to rise, to reach a higher maximum, at stations further up the estuary than at those further seaward. This phenomenon is more noticeable in the Itchen than the Test, since it is a more tortuous waterway. In the Itchen, too the

TABLE I.

	Lunitidal Intervals		Height above P.L.W. Datum				
Place	High Water F. & C.	Low Water F. & C.	Mean H.W. Springs	Mean H.W. Neaps	Mean L.W. Springs	Mean L.W. Neaps	Mean Level
	h. m.	h. m.	ft.	ft.	ft.	ft.	ft.
Southampton (S.H.B.)	10. 55 12. 57	16. 29	13¼	11½	¼	3¼	7
Calshot Castle (S.H.B.)	11. 00 13. 02	16. 34	12½	10¼	½	4	7
Redbridge (S. Rly.)	10. 50 12. 52	16. 29	13¾	11½	2¼*	3	–
Woodmill (Univ. Coll.)	10. 45 12. 47	16. 14	14¼	12	4½*	5	–

* – Fresh Water Level.

acceleration of the times of the low waters as compared with the higher waters is greater than in the Test; this is, however, quite a typical feature of an estuarial tide.

In this same table the range of the tide, at different places in the waterway, and at springs as compared with neaps, is expressed as height above Port Low Water Datum (P.L.W.D.). The significance of the tidal range is referred to again below.

There are certain important features about the Southampton type of tide which one cannot, however, learn from a table such as this. Fig. 3 illustrates the shape of the curve of a typical spring tide, with an ordinary sine curve added for comparison. Although one could have learned of the two high waters from the table given above, one could not have had any reason to suspect the peculiar shape of the curve on the rising tide. The tide, in fact, appears to hesitate in its rise, and there is a suggestion of a second low water which does, in fact, occasionally occur—about three hours after the main one. The first rise after the main low water is known as the **young flood,** although locally this term is sometimes used for the "flattening" which follows it. It is also worth noticing from this diagram that the interval between low

Tidal Phenomena—continued

water and the succeeding **first** high water is the same as between that low water and the preceding first high water.

Fig. 4 illustrates a Portsmouth and a Portland tide for comparison. At neither place is a double high water observed. But whereas at Portsmouth the " young flood " is less distinct than at Southampton, at Portland it has become a clearly distinguished second low water, known locally as the " Gulder ".

TABLE II.

		M_2	S_2	N_2	K_2	K_1	O_1	P_1	M_4	MS_4	A_0
DEVONPORT	H ft.	5·6	2·1	0·9	0·6	0·2	0·4	0·1	0·5	0·3	8·8′
	g°	145	194	107	194	133	006	133	111	177	
PORTLAND	H ft.	2·1	1·1	0·5	0·3	0·3	0·2	0·1	0·4	0·2	3·2′
	g°	194	243	184	239	113	344	109	030	082	
POOLE ENTRANCE	H ft.	1·2	0·6	0·5	0·2	0·3	0·2	0·1	0·6	0·4	3·6′
	g°	271	293	239	293	113	330	113	031	077	
SOUTHAMPTON	H ft.	4·5	1·3	0·9	0·4	0·3	0·1	0·1	0·8	0·5	7·0′
	g°	329	015	310	017	114	005	096	019	077	
PORTSMOUTH	H ft.	4·7	1·5	0·9	0·4	0·3	0·1	0·1	0·7	0·5	7·2′
	g°	326	011	303	009	111	344	095	013	068	

From the point of view of harmonic tidal constants, we can consider the curves of known or alleged astronomical significance which, when combined together, give a very close approximation of the actual tide. Table II is a statement of the tidal features at Southampton and certain other South Coast ports. A_0, in the last column, refers to mean sea level at the port in question, and gives its height above P.L.W.D. A_0 serves as the axis about which the various curves are to be drawn, which are given by the data in the preceding columns. For these curves it is necessary to know the height (or amplitude) and angular times (or phase-lag) of each of them at the place concerned. Height is expressed by H (in feet), and time by g (in degree).

Since M_2 is at most British stations the most significant tidal constituent, times of high and low water usually correspond fairly closely with what the times would be if this were the sole constituent. For example, if, in respect to Southampton, one divides g (329°) by 29, one obtains a figure of approximately 11, which is the hour of first high water, as given in the " non-harmonic " table above. What is important to notice is that, at Southampton, Poole, Portland, and even Portsmouth, the constituents M_4 and MS_4 have a relatively significant amplitude as compared with most British ports. Although these places are situated near a node or amphidrome for M_2, they are not so situated in respect to these minor constituents.

Fig. 5 shows the tide for 15/9/1935, as predicted for Southampton, using not only the seven constituents given in the Tables, but a total of 25; the figure also gives for comparison the tide which actually occurred. It is clear that in this particular case the harmonic method is very tedious to apply. But here is one of the most difficult tides in the world to predict, and it must not be supposed that such complications are commonly met with.

In the case of the vast majority of ports, the seven constituents normally quoted in the Tables are sufficient to give an excellent picture of the tidal règime. All that is needed is to draw the regular sine curves for each constituent, and combine them graphically in order to reproduce a very close likeness to the tidal curve, which records what actually occurs. No other method of description can approach it for conciseness and accuracy.

If one were to attempt to describe the Southampton tides in strictly astronomical terminology, one would say that the local tidal règime was fundamentally **synodic**—i.e., varying with the phases of the moon, and exhibiting the normal features of springs and neaps as at most European stations—but more noticeably

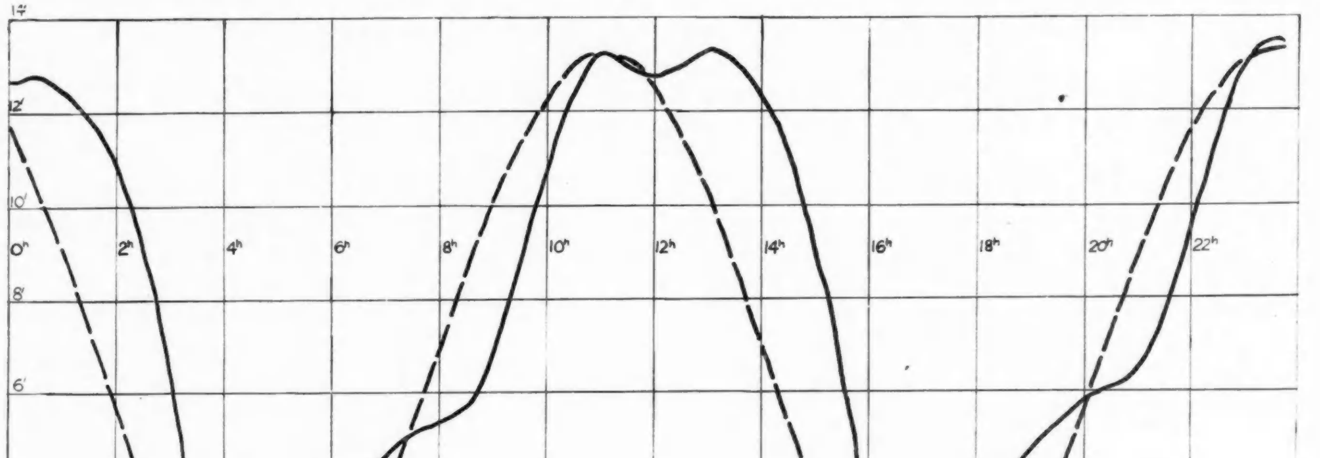


Fig. 3. Diagram showing relationship between a typical Southampton Spring Tide and a simple cosine curve.

Tidal Phenomena—continued

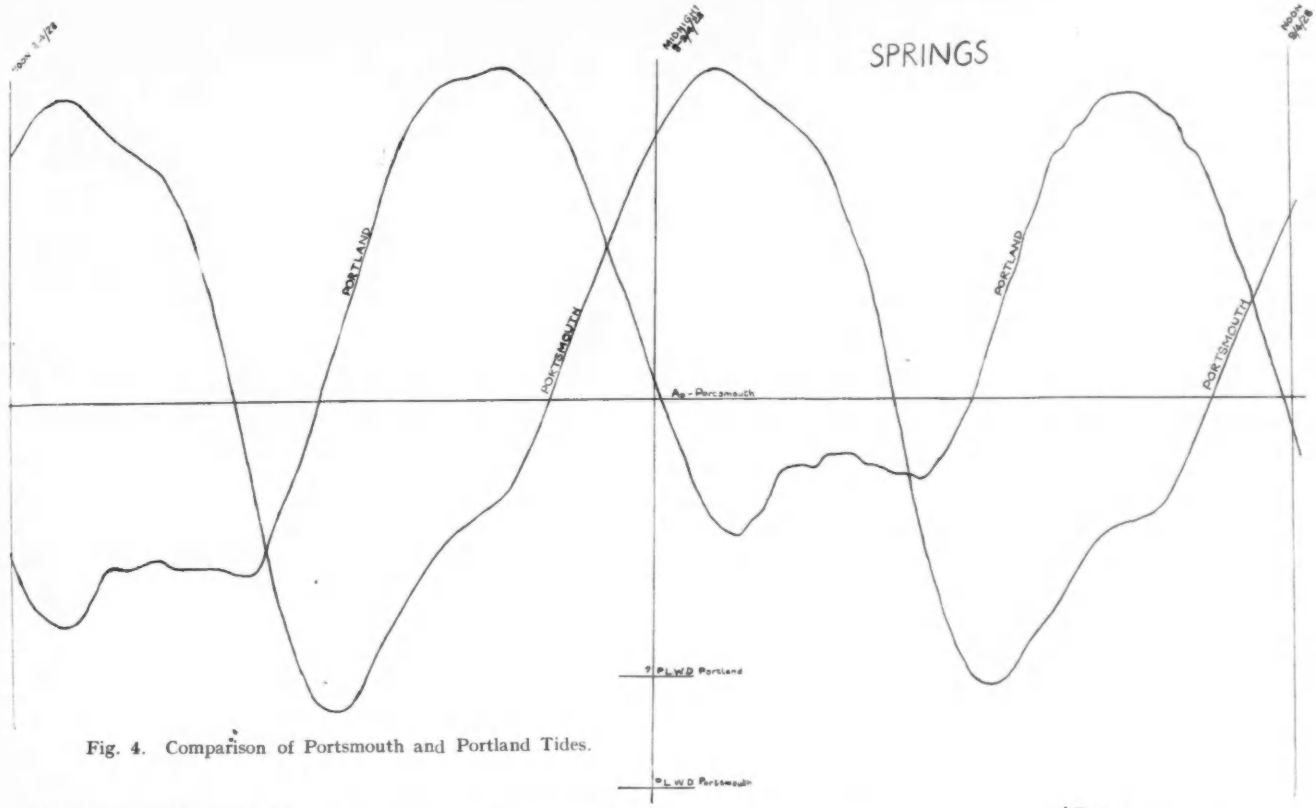


Fig. 4. Comparison of Portsmouth and Portland Tides.

anomalistic than **declinational.** The feature of a tide which is primarily **anomalistic** is that it varies strikingly according to the moon's distance. The Southampton tides do this to a certain extent. Thus if perigee coincides with new or full moon, the spring tides may be several feet greater in amplitude than at apogee springs. To a small extent the Southampton tide is declinational, in that heights of one tide and the succeeding one twelve hours later may be slightly different (at the time of spring tides, it is the morning low tides which are the lower, and the mid-day (first) high tides which are the higher). This latter feature is more noticeable at stations to the west of Southampton, including Portland. These facts are, however, stated with much more finesse and accuracy in the table which gives the value of H and g for the different constituents. Attention in this paper is given primarily to the vertical component in tidal movement, but the horizontal one is also of great significance to the mariner and to the harbour authorities. There is a very close relationship between the two, but it is not perfectly understood. Sometimes it is more fruitful to approach a difficult tidal problem by a consideration of the horizontal movements than it is by confining attention to the vertical rise and fall. Since for practical purposes tidal streams are often of great significance, there are a few points which should be indicated in the case of Southampton.

Table III and Fig. 6 show in tabular and in graphical form the relationship between tidal heights and direction of flow of the water a few feet below the surface. In the Western Approach the end of the Young Flood is clearly correlated with a change in the direction of the tidal stream. In the graphical diagram, referring to the waterway off Hythe Pier, the interesting things to notice are: (i) the periods of slack water, both at springs and neaps, which are invaluable for manœuvring big ships. In a deep estuary like Southampton Water, this is perhaps of more significance than the actual recurrence of "highness" of the water level. (ii) At the head of Southampton Water the periods of slack water are more pronounced than at Calshot or in the Solent. This is correlated with the fact that the "doubleness" of the high water is more distinct up the estuary than further down. This is interesting theoretically, for it suggests that in running up

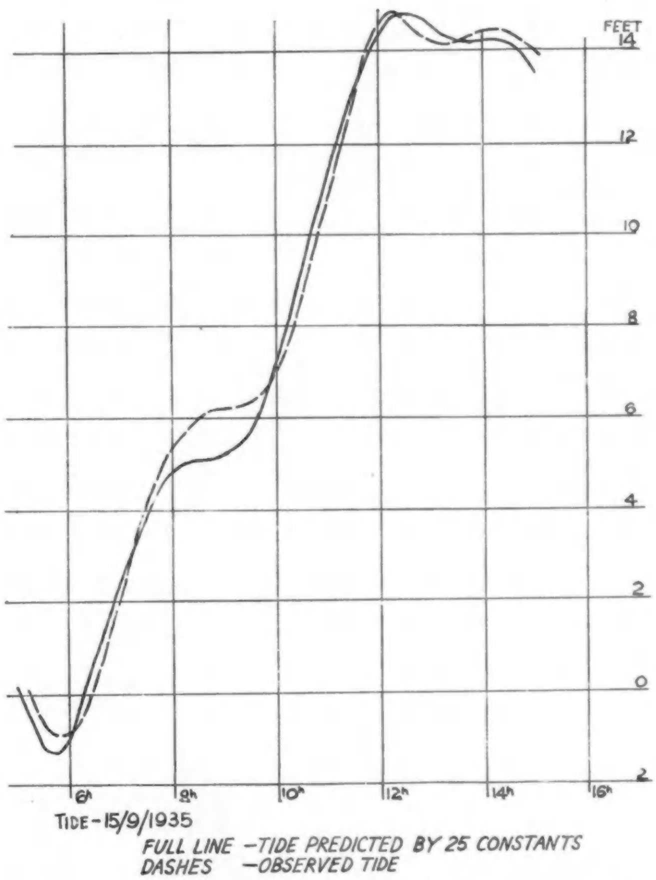


Fig. 5. A predicted and an actual tide at Southampton compared.

Tidal Phenomena—continued

TABLE III.

WESTERN APROACH

Hours		Direction	Rate (Knots) Springs	Rate (Knots) Neaps	Remarks
Before Low Water, Town Quay	6	223°	0·8	0·4	First H.W. Town Quay
	5	231°	2·1	1·0	
	4	236°	1·8	0·9	Second H.W. Town Quay.
	3	231°	1·7	0·8	
	2	230°	1·4	0·6	
	1	226°	0·9	0·4	
Low Water	0	Turning	0·0	0·0	20 Min. Slack Period Before East-Going Stream
After Low Water, Town Quay	1	057°	1·1	0·5	
	2	057°	1·0	0·5	
	3	055°	1·0	0·5	
	4	055°	1·3	0·7	Maximum East-Going Rate
	5	044°	1·0	0·5	
	6	223°	0·2	0·1	5 min. Slack Before W.-Going Stream
	6½	225°	0·8	0·4	First H.W. at Town Quay

DOCK APPROACHES OFF HYTHE PIER

Hours		Direction	Rate (Knots) Springs	Rate (Knots) Neaps	Remarks
Before Low Water, Town Quay — Ebb	6	323°	0·5	0·3	First H.W. Town Quay, 5½ h. Before L.W.
	5	089°	0·1	0·0	
	4	Slack	0·0	0·0	Second H.W. Town Quay; 20 Mins Slack
	3	113°	0·3	0·2	
	2	131°	1·1	0·6	
	1	134°	1·9	0·9	Maximum Ebb Stream
Low Water	0	129°	0·3	0·2	
Young Flood	1	325°	0·7	0·4	
	2	332°	0·6	0·3	
	3	353°	0·3	0·2	
After Low Water, Town Quay — Flood	4	Slack	0·0	0·0	20 Min. Slack Period
	5	323°	1·1	0·6	Maximum Flood Stream
	6	321°	0·9	0·5	
	7	Slack	0·0	0·0	20 Min After First High Water

the estuary, two inter-penetrating waves appear to be separated out owing to frictional retardation. This " separation " is more noticeable at springs than at neaps. For shipping this is very fortunate, since it ensures some slack water even on the highest springs. (cf. Portsmouth, where only rarely, and then at neaps, does a real double high water occur. At springs there is only the faintest sign of it, and consequently there is a far shorter period of slack water. At Poole Harbour, on the other hand, it is much more noticeable than at Southampton.)

It is important now to say something about the relationship between depth of water available at Southampton and the tidal règime. As to the depth of water available below P.L.W.D. in the various parts of the waterway, one can say that there is a ruling depth of over 35 feet even at low water; it is thus possible to bring some of the largest ships up and down the channel at most states of the tide, but there are occasional cases of vessels going aground through failure to appreciate the exact shape of the tidal curve on the day in question, as well as to forecast correctly the exact time of the slack water period. Fig. 7 shows the amount

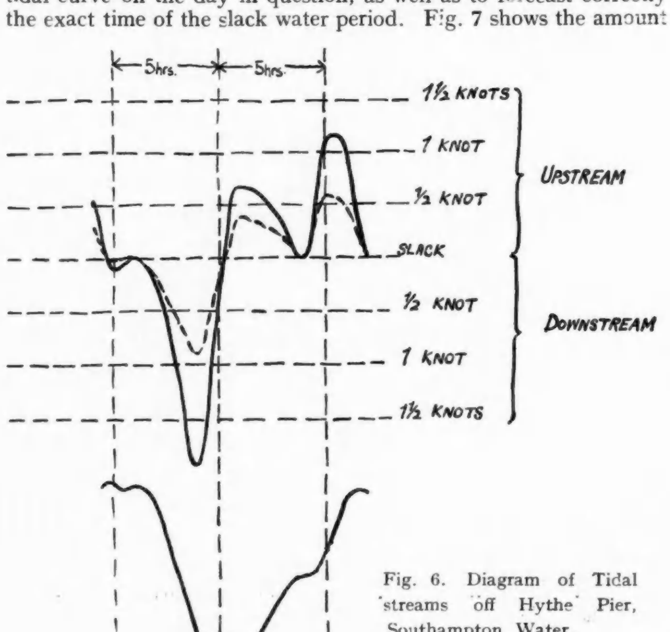


Fig. 6. Diagram of Tidal streams off Hythe Pier, Southampton Water.

of water available **above** P.L.W.D. at different hours on one particular day in 1937; the heights taken on constructing this diagram are actually recorded ones and not predictions. It must be remembered that the water level may, and at Southampton frequently does, often fall below P.L.W.D., and in this connection it is worth quoting from the Admiralty Tide Tables (Part III): " The chart datums used by different nations differ considerably, and those of the Admiralty sharts are those which were used by the original surveyors. When the datum is low, the predicted height of low water, referred to chart datum, is nearly always positive and must be added to the charted depth; if the datum is high, the predicted height is frequently negative, and must be subtracted from the charted depth. The charts, therefore, do not always show minimum depths and vessels have grounded through failure to appreciate this fact ". At Southampton chart datum is somewhat high, and at perigee springs may fall to noticeably over a foot below P.L.W.D.

It has been noted above that spring tides occur in north-western Europe about three days after Full and Change. The

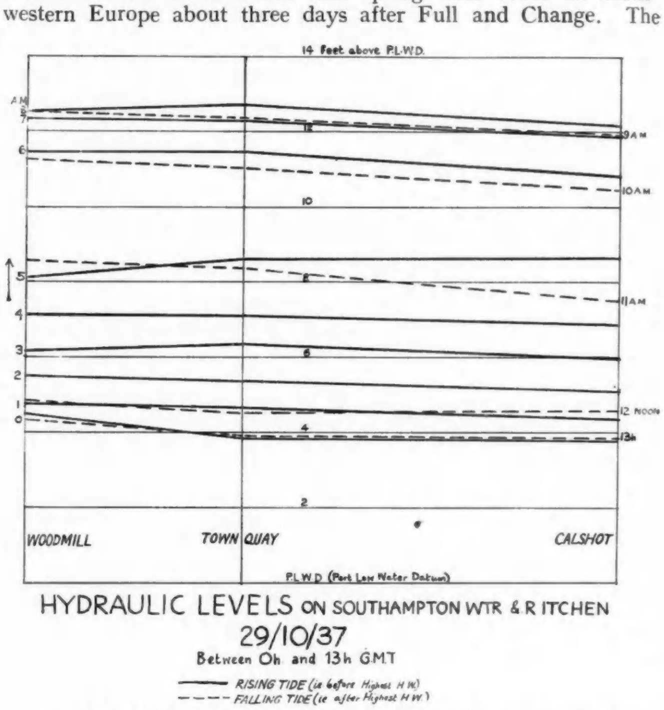


Fig. 7. Heights of water above P.L.W.D. in Southampton Water at different hours during one day.

way in which this comes about cannot easily be explained, but it appears that the oscillatory systems in some peripheral waters are stimulated only indirectly by the astronomical forces; the direct stimulation comes from contact with one of the oscillating systems of the open ocean. Without taking the investigation too far back, it can be appreciated that if the tides in the English Channel are stimulated by the tide in the neighbouring part of the North Atlantic, the spring tide will occur one tidal period later than in the latter. In the North Sea the tide in the northernmost oscillating section will be in a similar position, and in the southern ones springs will occur respectively two and three tidal periods later.

Now it has been observed at Southampton that the second high water reaches its greatest height a little later after full and change than does the first high water. This gives rise to some speculations to the influence of the North Sea tides on those of the English Channel. Since meteorological perturbations due to the passage of intense weather systems in the North Atlantic would reasonably be expected to suffer the same delay as the spring tides in transmission through several oscillating systems, a very interesting investigation is suggested. By making these assumptions, it may be possible to forecast deviations due

(concluded on page 154)

High Lift Navigation Locks

Some Recent Examples in America*

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Introductory

PREVIOUS papers that have been presented to the Permanent International Association of Navigation Congresses and published in their proceedings include several reports relating to American locks of low or moderate lift. The trend toward the development of water power in conjunction with navigation has resulted in the recent construction of locks of much higher lifts. Outstanding examples are the Tennessee River locks at the Chickamauga, Wheeler, Pickwick Landing and Gilbertsville projects, the Bonneville lock on the Columbia River, and the Pinopolis lock on the Cooper River. Principal dimensions of these locks and one other which is under design are shown in the following table.

Table 1

Name of Lock and State	River	Lock Dimensions: Chamber Width Clear	Chamber Length Clear	Lift at Low Water	Project Depth	Gates: Type	Height: Upper	Height: Lower	Date Opened to navigation
		Ft.	Ft.	Ft.	Ft.		Ft.	Ft.	
Bonneville, Oregon	Columbia	76	500	65	26	Mitre	45	102	1938
Chickamauga, Tennessee	Tennessee	60	360	46	9	Mitre	27	71	1937
Gilbertsville, Kentucky	Tennessee	110	600	44	9	Mitre	46	90	Under Const.
Pickwick Landing, Tenn.	Tennessee	110	600	53	9	Mitre	25	77	1937
Pinopolis, South Car.	Cooper	60	180	70	9	Mitre	32*	93*	Under Const.
St. Anthony Falls, Minn.	Mississippi	56	400	49.7	9	—	—	—	Under Design
Wheeler, Alabama	Tennessee	60	360	44.7	9	Mitre	25	67	1934

* From sill to top of wall

Prior to the construction of the locks listed in the foregoing table, outstanding examples of the higher lift locks that had been constructed in the United States, all of which were for barge navigation, were :

	Lift Ft.	Date Completed
Illinois Waterway at Lockport, Illinois	41	1933
New York Barge Canal at Little Falls, New York .	40.5	1919
Mississippi River at Keokuk, Iowa	40	1913
Mississippi River at St. Paul, Minnesota	38	1917
Tennessee River at Wilson Dam, Alabama ...	89 (in 2 lifts)	1927

Discussion of the design, construction and operation of the second group of locks appears unnecessary because that of the more recent locks of higher lift will cover the problems involved in those locks which may now properly be classed as locks of medium lift.

Problems involved in Design

(a) Choice of Type. With suitable foundation conditions, the determination of the type of structure, whether one, two, or more locks, mechanical lift, or incline, or even the transfer of cargo, should be largely dependent upon relative cost. Consideration must be given to the interruption of navigation during construction, density of traffic, intended capacity of the structure for commerce, need for economy in the use of water, time required for transit, safety to boats, space available for the structures and for additional facilities when expansion is required, interruption to navigation during repairs, and many other matters equally important in arriving at the correct solution. Though it may run counter to practice, there are, nevertheless, cases where the transfer of cargo would prove to be the economical and sound solution.

It is readily seen that up to certain limits of wall height and with ordinary foundation conditions, the cost of locks per foot of lift decreases as the height of lift increases. Estimates made by the authors for a proposed canal which involved locks of various lifts gave the following average results for barge locks founded on rock at favourable elevations. The locks were 56-ft. wide, 400-ft. centre to centre of pintles, with depth of 12-ft. on the sills :—

Table 2

Lift Ft.	Cost per Foot of Lift* $	Ratio of Cost
10	57,500	1.00
15	43,600	0.76
20	37,000	0.64
25	33,600	0.58
30	31,500	0.55
35	30,200	0.52
40	29,000	0.50
45	28,300	0.49

* 1940 Figures

The estimates should be considered as relative rather than actual, due to changes in construction costs since they were made.

(b) Location. The location of the lock is dependent on many things, such as alignment of the river, approach depths, velocities, presence of eddies, islands, silting conditions, wind action, bridges and other structures that might adversely affect easy access. These factors are equally important for all locks without regard to the lift. They also have a bearing on the location of the dam, powerhouse, and other structures of the project, all of which must fit into the best solution of the problem, and concessions often must be made in locating some of the structures in order to effect a satisfactory answer to the entire problem.

(c) Foundations. The nature and supporting strength of the foundation has a definite bearing on the choice between single or multiple lifts, as well as on the design of the individual parts of the structure. While the design of a high-lift lock can be adapted to weak rock, gravel, sand, or earth, it may be costly and uneconomical construction as compared with a multiple lift. Structural design of high-lift locks is materially simplified by the presence of a foundation of sound rock.

(d) Type of Walls. The type of wall will depend largely on the foundation strength and its elevation with respect to the chamber floor, if of bedrock. Other factors affecting wall design are : filling and emptying system, need for water-saving chamber, and for future expansion of facilities. Generally mass gravity walls are used. However, hollow or earth-filled cells can sometimes be used in large walls with considerable economy, greater speed of construction, and better load distribution on the foundation. Bonneville chamber walls, shown on Plate I, are an example of special designs to meet unusual local conditions.

(e) Hydraulics. The principal hydraulic problems relate to the provision of a safe and easy entrance and exit for boats and barges, and also a rapid filling and emptying of the chamber without undue pitching of the craft. Satisfactory solution of these problems in high-lift locks is particularly important and ordinarily involves the aid of hydraulic laboratory models along with the results of actual operation of locks already constructed.

If the filling intake can be located on the outside of the lock wall at the upper approach, as at Bonneville, well and good; but if not, the location, number, size, and shape of the intake passages require careful consideration to develop an efficient design that will avoid objectionable disturbance in the chamber approach. Important are the location of intake passages at considerable depth below the water surface and in making them as large as practicable. Care is necessary to avoid air entrainment through vortex

*A Paper presented at the International Navigation Congress, 1949, in respect to Section 1 Question 2, "Means of Dealing with Large Differences in Head." Reproduced by permission.

High Lift Navigation Locks—continued

formation at the intake, and through valve wells, and the bulkhead passages which enable their unwatering, since same causes vacuum, vibration, water hammer, surges in the culvert system, and increased turbulence in the chamber (sometimes spontaneous). Unless means of venting are used, air often becomes trapped or pocketed in the culvert system, accumulating until sufficient pressure develops to force its release through the water passages with explosive violence, shooting water and air at spouting velocity in all directions free to it.

At Pickwick Landing and Pinopolis locks, air entrainment through the valve well and bulkhead passages is prevented in a very interesting way. See Plates 2 and 3. This is described in detail in later paragraphs.

The design of the culverts, laterals and ports, their number, shape, location and size, should be carefully studied with a view to minimising disturbance within the chamber while filling. Emptying of the lock chamber generally presents only the problem of avoiding vortex formation in the chamber and disturbance in the channel just downstream from the lock. Satisfactory solution may involve lengthening or modification of the lock walls, at considerable expense, to improve distribution of the water in the channel. For example, the culvert may be extended into the guide wall and the water released through its two sides.

(f) Structural Design. The masonry design problems are ordinarily similar to those involved in low-lift lock design. Important, however, are (1) the necessity for massive thrust walls to take without deflection the great load imposed by the downstream lock gates, and (2) the possibility of using cellular construction or thin reinforced concrete for the chamber and upstream breast walls.

For filling and emptying valves, the tainter or sector type is particularly well adapted to high-lift locks. The design is relatively simple and economical, sealing against leakage is simple, and operation is very satisfactory. Accessibility for repairs and ease of replacement are important factors in the design of valves.

Mitering lock gates have ordinarily been used for high-lift locks. For the upstream gate, where the breast wall is high, a floating submersible gate, which is raised and lowered into the breast wall by the admission and expulsion of air, offers a satisfactory solution. Gates of this type are in use at the Keokuk lock on the Mississippi River in Iowa, and the Wilson lock on the Tennessee River in Alabama. Considering downstream gates of the mitering type, the use of an air or flotation chamber effects operating economies. Inasmuch as the gates are very heavy (one leaf of the gate at Bonneville, Oregon, weighs 525 tons in air), are suspended from but two points when open, and have a tremendous water pressure against them when closed, it is imperative that they be amply stiff and rigid. Sealing against leakage is also important.

The provision of an emergency dam to enable the prompt damming of the lock against a swift flow of water in case of a major accident to a gate is generally recognised as a necessity. Extra gates called guard gates are frequently used to protect the service gates but they are not, in the true sense, for emergency use since they cannot be operated to stop a rapid flow of water through the lock. The fundamental requirement of the emergency dam is that it serves the emergency it is designed for. The design should be both simple and sturdy. Selection of type will be governed by width of lock, depth on the upper sill, and other factors. There are but few cases on record of a major accident to lock gates, and in not all of these cases were emergency dams available for use, so that the success of the different designs has had little opportunity for being proven. The authors are fully aware of the local conditions at most locks that prevent the testing of such a dam under conditions similar to those attendant with an emergency. However, they wish to impress engineers who are responsible for the design and operation of locks with the need for testing emergency dam installatiins in so far as practicable. At any rate, trial operations in still water should be made frequently enough to insure the proper skill of the operating crew and the maintenance of equipment.

(g) Mechanical Design. Many of the mechanical problems associated with high-lift locks are similar to those for lower lifts. Chain fenders and floating mooring bitts are, however, more properly associated with the design of high-lift locks.

Either chain or cable fenders for protecting the lock gates have been installed at the Panama Canal locks, Welland Canal locks, and Bonneville ship lock. Frequently a chain is suspended from each mitre gate leaf and connecting with the lock wall to give some protection at a minimum of cost.

At Panama locks the upstream and downstream approaches are

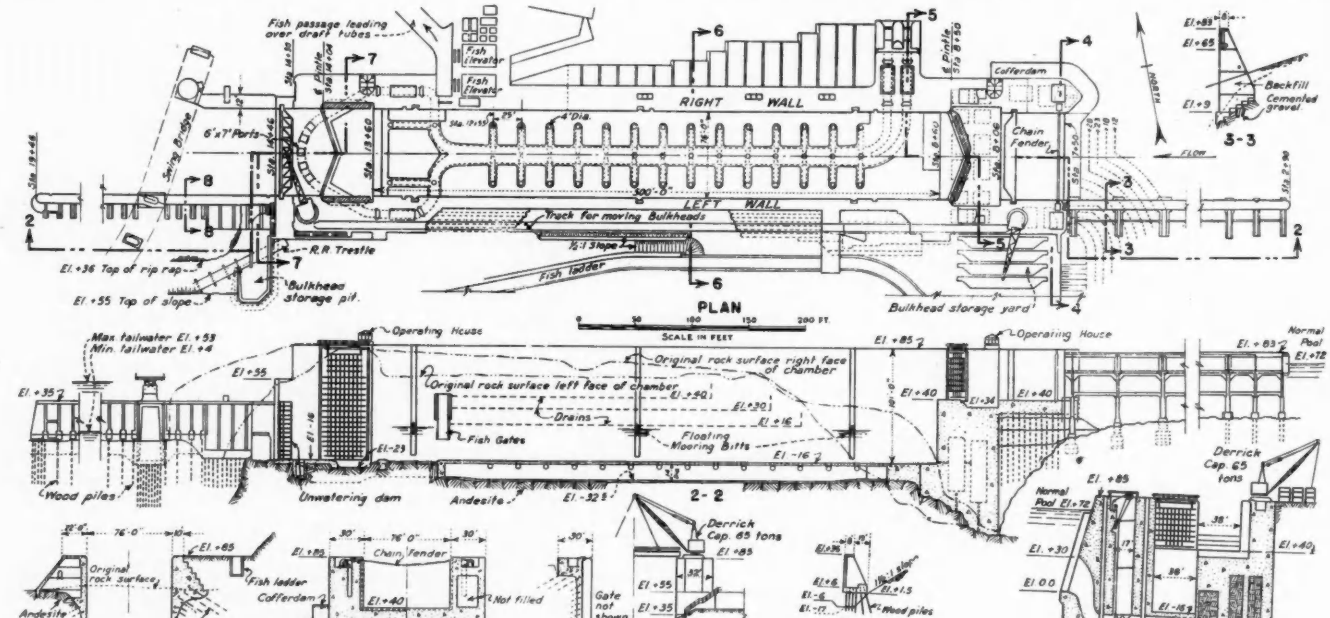


Plate 1. Bonneville Ship Lock, Columbia River, Oregon.

High Lift Navigation Locks—continued

guarded, and also the upstream side of the intermediate gates.

At Welland locks all downstream gates are guarded on both sides, except the guard lock which is protected on the upstream side only. This lock has its upstream gates guarded on both sides, and the flights of three locks have the upstream side of all gates guarded.

At Bonneville protection is provided only at the upstream approach.

Different types of fenders are used on each of these waterways, as described below :

1. At Panama the fender is a 3-in. wrought iron chain which is lowered to the bottom of the channel to permit a boat to pass. This chain passes over a sprocket on each wall to a long hydraulic actuating cylinder, which acts as a shock absorber.

2. At Welland the fender is a cable suspended 3.5-ft. above normal water surface. The cable leads to bollards and brake drums having three circular flat friction sliding rings around the periphery and below the drum, which are held in contact by coil springs. The cable is supported at numerous points by lines from a boom on one wall. In order to permit the passage of ships the cable is disconnected and raised by the boom. After use of the fender cable for stopping a boat, the cable is returned to its proper position by hand-operated jacks.

3. The Bonneville fender consists of a stud chain suspended from sprockets attached to friction brakes and a drive shaft. Motor drives lower the chain into the bottom of the waterway to allow a boat to pass and then raise it to position to obstruct the channel where the friction brake will hold it in place. On hitting the chain a boat's movement will be retarded as the chain pays out from each of the two braking machines.

The need for such protective installations is governed entirely by local conditions, such as prevalence of high winds and currents, the extent of the damage that might result from wrecking a gate, inconvenience to navigation should it be suspended during repairs, and other factors.

When the usual type of fixing mooring bitts are used in high-lift locks, boats are necessarily hard to handle during a lockage, due to the great difference in pools and rapid change of levels in the lock. Floating mooring bitts which rise and fall with the water level eliminate this difficulty and provide for greater safety of the lock gates. Several types of floating bitts that have been developed are described in later paragraphs.

The following points are believed to warrant special mention :

1. Tainter or segmental valves for filling and emptying should be counter weighted.

2. The sealing of gates and valves is a more delicate problem because of the higher heads. The adherence to close tolerances in construction and the use of rubber adjustable sealing strips of "J" shape are suggested.

3. The authors believe that all machinery should be both simple in design and sturdy. The use of safety or shear pins that break under a predetermined strain is recommended as safeguards or insurance against more serious damage.

4. Accessibility for repairs and ease of replacement are important factors.

(h) Water Consumption. The average water consumption per movement for double locks of equal lift with any order of movement and for single lift locks with balanced movements equals one half the volume of the chamber between the upper and lower levels; whereas the consumption for a single lift with a succession of upstream or downstream movements is twice that volume or a full chamber. Therefore, the use of a single lift will actually result in greater water consumption.

(i) Operating Considerations :

1. Good communication between the lock and boat operators is very important. Telephone, radio, and simple systems of visual and audible signals are effectively used.

2. The operation controls for the lock should be located where good vision of the lock is afforded the operator. Gate controls should be close to the gates in order that the operator may closely watch their movement. Beceause of the deepness of the chamber, the operator should be close to the wall face. It is ordinarily desirable, in order to improve visibility, that the operating controls be well above the level of the lock wall.

3. The desirability of floating mooring bitts has been proven by experience.

4. The use of capstans, winches, or other suitable appliances to pull boats into and out of the lock becomes necessary where traffic is heavy.

(j) Representative High-Lift Locks. The subject of high-lift locks will be further discussed by describing three representative structures, namely :

1. Bonneville lock on Columbia River, a ship lock with clear dimensions 76-ft. by 500-ft., and a lift of 65-ft. at low water. The depth on the upstream sill at ordinary low water is 29-ft. and 26-ft. on the downstream sill.

2. Pickwick Landing lock on Tennessee River, a barge lock with clear dimensions 110-ft. by 600-ft., and a lift of 53-ft. at low water. The depth on the upstream sill is 21-ft. with 10-ft. on the downstream sill.

3. Pinopolis lock on Cooper River, a barge lock with clear dimensions, 60-ft. by 175-ft., and a lift of 70-ft. at low water. The minimum depth on sills will be 12-ft. The lock is designed so that the clear length may later be increased to 360-ft.

Bonneville Ship Lock

(a) Economy of Single-Lift Lock. For estimating relative costs, preliminary plans were made for both single and double-lift locks at this site. From these estimates it was found that the double-lift structure would cost approximately 15 per cent. more than the single-lift structure. Other advantages such as operating and maintenance cost, and time of lockage were apparent, and the single-lift, although of unprecedented height, was adopted. The small difference in water consumption in favour of the double lift was not an important factor due to the abundant stream flow at this site. The savings in estimated first cost were principally in concrete and machinery.

(b) Foundation Conditions. Foundation conditions were favourable to a single-lift, but unfavourable to a double-lift. (See Plate 1). The lock chamber of the former could be founded on the narrow rock dike barely wide enough for the length of one chamber. The rock is a strong lava with few seams, but of columnar structure in many places. The lock chamber was located in a great trench excavated through the dike with the thrust walls for the downstream mitre gates, which take a load of 17,500,000 pounds, resting on and backed by sound rock. The upstream end of the lock was founded on rock as deep as 85-ft. below sea level, necessitating walls of 170-ft. maximum height. The intake has the same low foundation. The downstream approach is in a deep cut in gravel and the guide wall is founded on wood piles.

The upstream guide wall is supported on high buttresses with spread footings founded on cemented gravel, or equally strong material, with a short section resting on wood piles.

(c) Hydraulics. The design of a lock with a lift of 65-ft. presented a major hydraulic problem. Model studies were therefore undertaken. The deep foundation at the upstream end of the lock afforded a good location for the intake, deep beneath the pool level, across the wall from the chamber and removed from the approach. Locating the valves below low tailwater prevents accumulation of air in the water passages when the valve is closed and the lock empty. Although other schemes were studied none of them offered such favourable conditions. The intake sill was placed at river bed level (elevation zero, mean sea level), from which the water drops 30-ft. to the filling valves through two inclined passages.

Two schemes for the longitudinal culverts were studied, one with a culvert in each lock wall and ports in the wall face discharging the water horizontally into the chamber; and the second with a single culvert below the lock floor, having numerous lateral branches with ports discharging the water vertically into the chamber. Economy of construction and better hydraulic conditions prompted adoption of the second plan. Considerable experimentation was conducted to establish the locations, number and size of ports; and while a satisfactory model solution was found, it was decided to equip the ports with anchor bolts, which would permit the installation of a plug should the need arise for changes in the

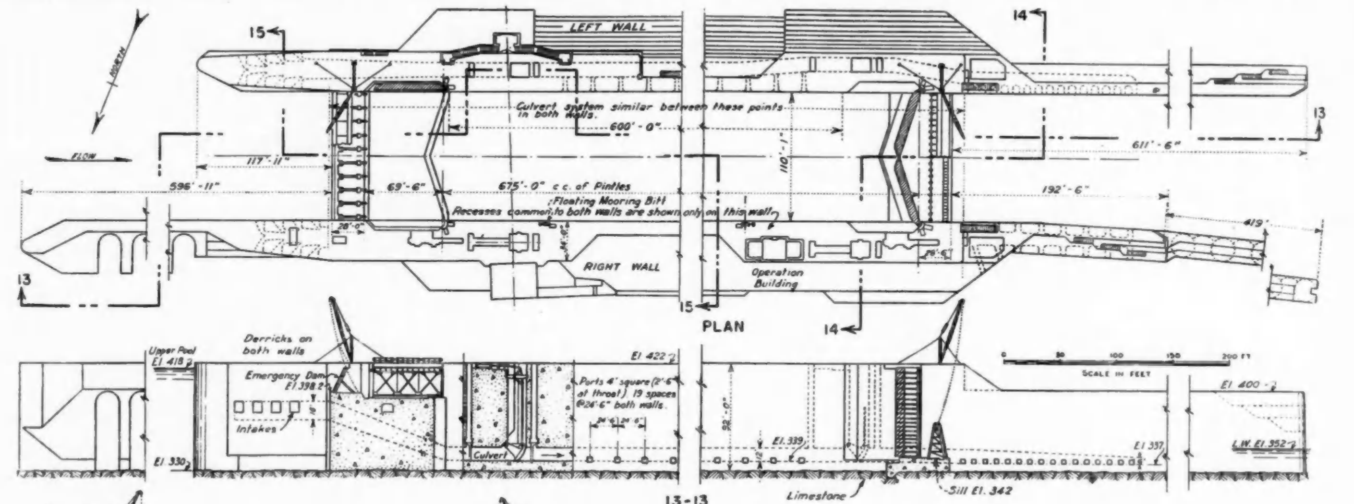
High Lift Navigation Locks—continued

distribution of the inflowing water as a result of actual experience. A port can thus be completely or partially closed by a diver without unwatering the lock chamber.

The only practical location for the emptying valves was in the lock walls, one in each wall, with a connecting culvert looped downstream in plan and under both the lock floor and the downstream mitre sill. Ports in the top of the culvert discharge just downstream from the gates. This scheme resulted in a heavy concentration of flow, with considerable turbulence at the discharge ports, making it necessary for boats to tie up along the guide wall just below the bridge to avoid objectionable velocities.

The hydraulic system is designed to prevent air entrainment, and should air be entrained it will be released without particular disturbances. An over-all filling efficiency of 79 per cent. has been observed with 64 per cent. in emptying.

The valve mechanism is controlled by two-speed motors which will permit valves to be opened slowly in order to reduce turbulence when the water in the lock chamber is at a low level. Valves can be opened at this low speed in about 6 minutes 30 seconds, whereas



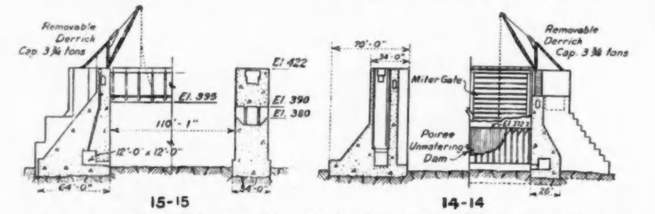


Plate 2. Pickwick Landing Lock, Tennessee River, Tennessee.

at high speed the operations takes only 2 minutes 20 seconds. Generally, however, the opening operation is started at low speed and then shifted to high speed when the head has been reduced sufficiently to prevent objectionable turbulence. Another means of reducing turbulence is to open only one valve at the beginning of filling operations.

(d) Structural Features. The chamber walls are of particular interest because of their height (102-ft.), and for the most part of their length and height they are formed by lining the chamber excavated in rock with a facing of concrete 3-ft. thick or more. Walls of several types, as shown on Plate 1, are built above the top of bedrock and this thin facing. The concrete facing was anchored into the rock with steel rods designed to take full hydrostatic pressure and as a further precaution drains leading to the lower pool were provided to prevent the building up of such pressure. The walls above bedrock were also securely anchored into rock at their base.

Because of the low bedrock at the upstream end of the lock and the resulting large foundation dimensions, this foundation was designed of cellular construction. The construction of the breast wall was complicated by the necessity of routing navigation through the lock during construction.

The masonry structure for the emergency dam and chain fender was the last constructed. Although this part of the lock connected with structures founded on rock, it was supported on wood piles driven into backfill which had been placed 27 months earlier. The joint which is closed by a water stop is designed to permit some vertical movement; however, none has been apparent.

The fish elevators and channel adjacent to the right wall necessitated heavy reinforcing in their vicinity; the block of masonry immediately dowstream was cantilevered horizontally at its base.

The mitre gates are framed of horizontal girders 6-ft. deep and 42-ft. 4-in. long, tapering at the ends. Only the downstream gates have flotation chambers. To reduce weight silicon steel was specified and buckle plates used wherever possible. The downstream gates, which are 102-ft. high, weigh 525 tons each. After erection the two leaves were without noticeable warp, and the meeting of the mitre ends was nearly perfect.

The bulkheads used for the emergency dam and also for unwatering the lock are made up of two horizontal trusses 82-ft. 3-in. long, and 10-ft. 5-in. deep. The trusses from the top and bottom of a bulkhead section 3-ft. 9-in. high, with plating on the compression chord side. As light weight was important to facilitate handling, nickel steel was specified. The bulkheads, the heaviest one weighing 32 tons, are equipped with four lifting pins. A roller assembly at the ends reduces friction so as to permit installing them in a strong current. A flat car running on a standard gauge railroad track along the left wall of the lock is used to transport the bulkheads from one end of the lock to the other. The car is moved by cables.

The filling and emptying valves are of the tainter or segmental type, 7 by 11.5-ft. in size, and are counterweighted.

(e) Mechanical Features. The outstanding mechanical problems were associated with the operation of the emergency dam and the chain fender. In order to avoid jamming of the bulkheads in the recesses, a roller housing of cast nickel steel is pivot mounted in the ends of the bulkheads, the rollers which take the thrust being flanged. A lifting beam containing four automatic fastening and unfastening hooks is used to handle the bulkheads. The use of post-type derricks (capacity 65 tons) for handling the bulkheads saved considerable wall space and presents a pleasing appearance.

Chain fender machines were designed with a view to improvement over previous designs. A drop forged detachable stud link chain made of alloy steel was used. Links are 1-5/8-in. stock and are 9-3/4-in. long and 5-7/8-in. wide and designed to break under a pull of 325,000 pounds. The fender is designed to stop a 10,000 ton boat travelling at 4.5 miles per hour in a distance of 72-ft. Dynamometer tests were made to adjust the brakes.

The floating mooring bitts installed at Bonneville are mounted on top of air-filled tanks of 93 cubic feet capacity, which float in vertical recesses in the face of the chamber walls. The bitt assembly rolls in the recess on bearing tracks and guides. Operation

High Lift Navigation Locks—continued

has been successful, but there is the possibility that a boat may strike and damage the tank, which is 4-ft. wide and exposed at the face of the wall. A similar design made later for the Chickamauga lock, Tennessee River, minimises this possibility by installing the tank in a well in and near the face of the lock wall, with the mooring hook, which is on the side of the tank, accessible through a vertical slot only 16-in. wide.

(f) Electrical Features. Electricity is used for lighting and all power needs. The circuit is directly connected to the station service and main hydroelectric generators in the adjoining power house, and to a public service system. All power machines are provided with signals and interlocks to protect against mistakes in operation. Interlock by-passes are used to permit testing and repairing of a machine by individual control without interrupting the use of the lock.

Two operating stations near the mitre gates on the right wall control the operation of the lock. Good vision is afforded the operator.

small boats, the time of filling the chamber is adjusted to the weight of the boat, varying at normal stages from 11.5 minutes for the largest to 27 minutes for the smallest boats. Navigators are enthusiastic in their commendation of the floating mooring bitts, and experience no difficulty in navigating or tying up in the upper or lower approaches at ordinary stream flow. During floods Columbia River currents are strong and some difficulty is encountered at the entrance to the lock approach channels.

The mitre gate seals permit very light leakage under full head.

Minor troubles have developed in the electrical equipment from condensation. These have been corrected by the installation of forced draft ventilation and the transfer of pump motors from within to outside of gate flotation chambers by the use of a long shaft drive. The electrical interlocks require adjustment about once a month.

On several occasions a filling valve has not seated tight due to some small drift being caught under the seal. This caused vibration in the valve and operating struts which continued until the obstruc-

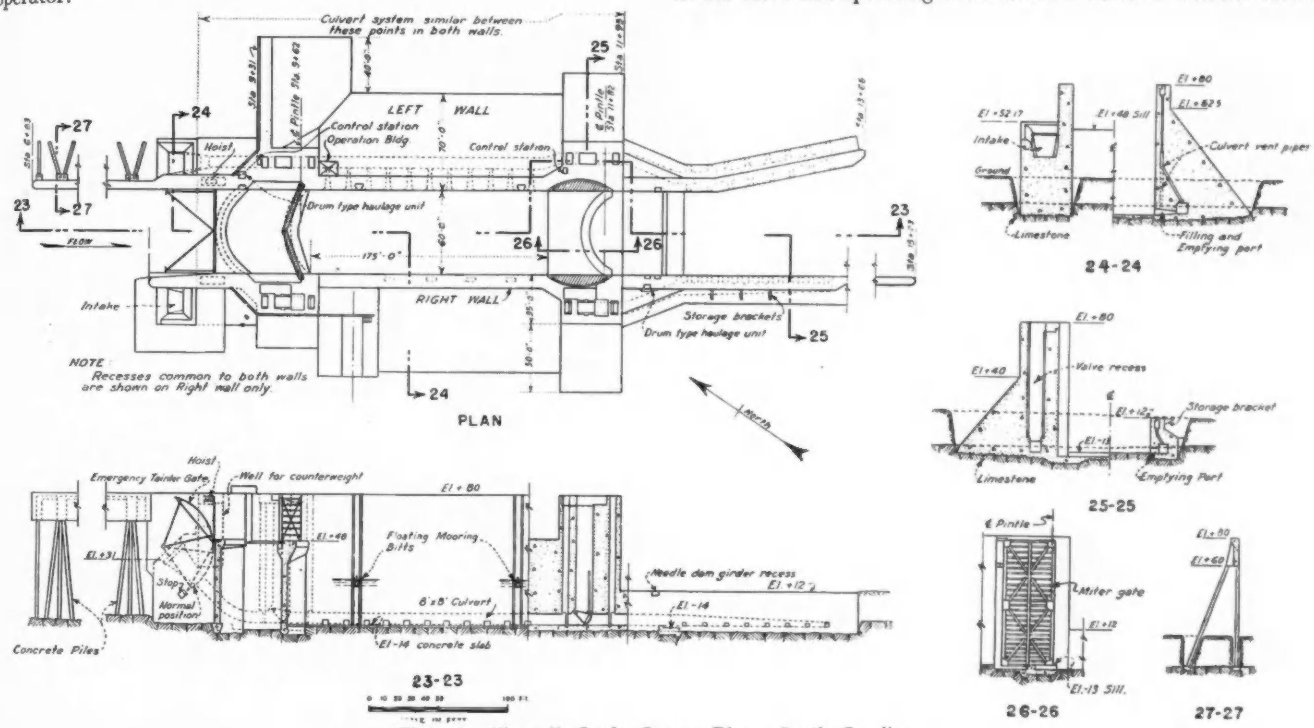


Plate 3. Pinopolis Lock, Cooper River, South Carolina.

(g) Cost. Bonneville ship lock cost approximately $4,500,000, exclusive of the approach channels and the bridge across the lower approach channel. This amounts to roughly $69,000 per foot of lift, and $1.04 per cubic foot of chamber volume.

The cost is made up of the following features :

Table 3

1.	Chamber walls and water passages	70.8 per cent
2.	Mitre gates and operating machinery	13.1 ,, ,,
3.	Diversion and pumping	4.7 ,, ,,
4.	Guide walls	4.1 ,, ,,
5.	Emergency dam bulkheads and derricks	4.0 ,, ,,
6.	Tainter valves and operating machinery ...	1.8 ,, ,,
7.	Chain Fender	1.2 ,, ,,
8.	Floating mooring bitts	0.3 ,, ,,
	Total	100.0 per cent

(h) Operation. At this date (June, 1939) Bonneville lock has been in successful operation for eighteen months. Except for one ship that passed during a high river stage, only shallow draft boats have used the lock as the downstream ship channel is not yet completed. Canoes, fishing boats, yachts and freight boats are locked through promptly and safely, inasmuch as the valve controls permit very flexible operation. In order to avoid too great disturbance for

tion was cleared. Trash bars on the intake prevent any but small drift from getting into the water passages.

Due to the limited commerce, facilities for pulling boats into or out of the lock have not been installed. Provisions have been made in the lock walls for installing capstans for this purpose when warranted by the needs of commerce.

Pickwick Landing and Pinopolis Locks

Pickwick and Pinopolis locks are illustrated on Plates 2 and 3. Only those features that are different from Bonneville will be described.

(a) Chamber and Guide Walls. Bedrock is found at approximately the level of the chamber floor. The chamber walls are therefore designed of gravity type. Those at Pickwick are 92-ft. high, while the Pinopolis walls are 96-ft. high. Guide walls are of gravity type except the upstream wall at Pinopolis which is of reinforced concrete as at Bonneville but supported on pre-cast concrete piles which are seated on prepared footings. At Pickwick Landing an extension wall is being added to the downstream right wall in order to improve the entrance condition. The upstream part of the wall rests on cells of steel sheet piling filled with concrete while the downstream part will consist of three large pontoons each 145-ft. long extending to an anchor pier.

High Lift Navigation Locks—continued

(b) Intakes. At Pickwick Landing the intakes, four in number with four openings each, are located just above the emergency dam on both sides of the two approach walls with 38-ft. of depth over their sills. At Pinopolis the intakes, two in number with one opening in each, are located on the outside faces of both approach walls with a depth of 29-ft. on their sills.

(c) Filling and Emptying Systems. Since gravity walls are used, they provide ample space for placing the filling and emptying culverts in the chamber walls, which under this condition is the most economical location. The culverts drop from the intake to the level of the chamber floor and extend longitudinally through the walls with frequent ports in the wall face. On one side the emptying culvert extends into the guide wall with ports on the inside face, while in the other it extends into a short approach wall with ports on both sides.

The designs were based on extensive model studies which developed very efficient hydraulic passages.

Air entrainment into the culverts is minimised by placing the Tainter valves in reverse position with the sheathing at the downstream side of the pits, thereby maintaining a considerable head of water in the pits and sealing same against air. Air and water-tight plugs are placed in the valve unwatering bulkhead slots slightly above the culvert, thereby sealing them against air entrainment. Vents lead from the culverts to galleries high in the walls where air and water are free to spout without damage.

Recent prototype tests have been made at Pickwick Landing, Wilson and Wheeler locks on Tennessee River. While the Pickwick design was based on model studies, the others were not. However, models have since been made and tested in order to get a comparison with the prototype. In all cases the models show a remarkably close agreement with the prototype. Tests at Pickwick Landing lock show an over-all hydraulic efficiency of 76 per cent. in filling and 62 per cent. in emptying.

(d) Emergency Dams. At Pickwick Landing the emergency dam is in 110-ft. long and 12-ft. high. This permits the use of a simple and economical folding wicket type dam. To erect the dam the wicket girders, normally resting at the bottom of the waterway, are raised by derricks on both walls, and connected at their tops to form a trestle on which roller mounted bulkheads are lowered on the upstream face of the vertical members.

At Pinopolis the dam is 60-ft. long and 27-ft. high. A new and interesting design has been developed. It consists of submerged Tainter gate mounted in reverse position, i.e., with the anchor arms extending upstreamward from the sheathing and therefore in tension. The gate, which is normally submerged below the sill, is to be raised by chain hoists to close off the channel.

(e) Unwatering Dams. At Pickwick Landing the emergency dam is used at the upstream end, but a structure 30-ft. high is necessary at the downstream end where a simple Poiree dam was installed. At Pinopolis where the waterway is only 60-ft. wide and a dam 25-ft. high required at the lower end of the lock, a needle type dam is planned. A horizontal girder placed slightly above the water surface will support the tops of needles, the lower ends of which will rest against a sill.

(f) Mitre Gates. Pickwick Landing upstream gates, which are 24-ft. high and 61-ft. 6-in. long, are vertically framed. The downstream are horizontally framed of parallel chord girders with tapered ends and plating on both faces.

Pinopolis upstream gates, which are shorter than Bonneville gates, are not tapered at the end. Comparative estimates for downstream gates arched and straight in plan showed a slight economy in favour of the arched design, which was adopted.

Air chambers were not used in the gates at either lock. Buckle plates were used only in the Pickwick Landing upstream gates.

(g) Tainter Valves. Tainter filling and emptying valves are used at Pickwick Landing and Pinopolis locks differing from the Bonneville valves only in that they are mounted in reverse position, that is, with the anchor arms extending upstream from the sheathing and in tension. This design provides a head of water in the operating well at all times and a seal against the entrainment of air.

(h) Chain Fenders. Inasmuch as the Pickwick Landing and Pinopolis locks are constructed for shallow draft boats chain fenders were not provided.

(i) Floating Mooring Bitts. The Pickwick Landing bitts consist of a hook mounted on a roller assembly which rolls in a narrow vertical recess in the chamber wall. The assembly is raised and lowered by wire rope, one end connected to a hand-operated winch located just beneath the top of the wall and the other end connected over sheaves to a floating tank located in a well in the lock wall, the bottom of which connects with the chamber allowing water to enter freely. This design make its possible by reeving of the rope, to cause the bitt to ride low or high with respect to the water surface, and also to raise the bitt to the top of the wall for inspection and repair.

(j) Power. Electric power for operating Pickwick Landing gates and valves is transmitted through oil actuated cylinders.

(k) Operating Controls. Pickwick Landing gates and valves are operated from control stations located near the upstream and downstream gates on both walls. All valves can be operated from each station and also the adjacent gates. Additional stations are located at the mid-chamber point on each wall. Each of these controls the operation of all valves.

(l) Facilities for Moving Boats. Pickwick Landing and Pinopolis locks are provided with single drum winches at the upstream and downstream approaches to pull boats into and out of the lock.

Tidal Phenomena

(concluded from page 148)

to meteorological causes from the predicted heights of the two high waters.

Another interesting problem in tides is the relationship between tidal heights and littoral growths. Fig. 8 shows the average height of the tide at Poole Bridge for each hour of the day during a lunation (actually the 29-day period, April 7th to May 7th, 1939). The mudbanks are uncovered more in the early morning and afternoon than at other times in the day, and they are on the average more deeply covered at night. This clearly is of

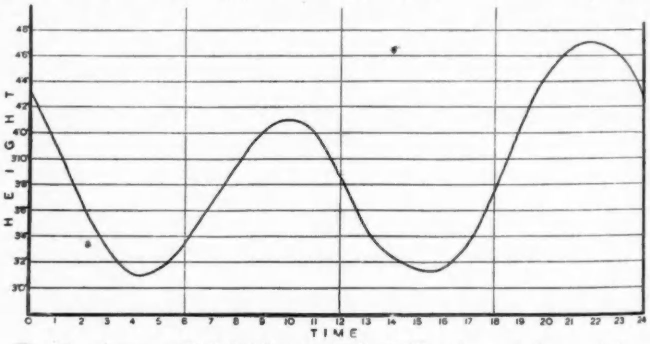


Fig. 8. Average tidal heights at Poole Bridge for each hour of the day during a lunation.

considerable ecological significance to plant and animal growths on the mudbanks, and consequently on the development of the mudbanks themselves. Since the shape of this diagram would slowly vary during the 19-year period referred to above, we may here have a partial explanation of the interesting spread and subsequent disappearance of rice-grass in Poole Harbour during this century. This and other effects of slow tidal changes offer an interesting field of investigation.

The author would express his thanks to Comdr. D. H. Macmillan, R.N.R., Hydrographic Surveyor to Southampton Harbour Board, for valued advice and assistance.

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Model Studies of Apra Harbour

Carried out by California Institute of Technology in Collaboration with United States Navy Bureau of Yards and Docks

ROBERT T. KNAPP, Director.

(concluded from page 129)

CURRENT FLOW.

The studies of water circulation within the harbour and its effect upon pollution and silting were productive of a quantity of useful data showing the complexities of water movement in basins of irregular shape. Investigations were also made into the effects of local winds, topography, tides and drainage, but here we will confine ourselves to waves and ocean currents. A current may be defined as a persistent water motion, whose speed may vary and whose direction may exhibit continuous change over a time interval much greater than the period of any cyclic disturbance associated with the current. There are several ways in which a current may arise, thus, a current may be produced by the restriction of the harbour entrance piling up the level of the sea above that of the harbour waters, or indeed within the harbour by narrowing entrances to inner basins. Progressive and standing waves may produce an oscillatory and translatory water motion or current. This translatory motion is termed "mass transport" and its magnitude even for storm waves is slight in the relatively shallow depths inside a harbour. Thus wave action in the harbour will produce a significant oscillating water motion whose amplitude varies as the height and length of the waves, and inversely as the water depth, but, unless the wave periods attain surge proportions, these motions will be localized in small areas of the harbour.

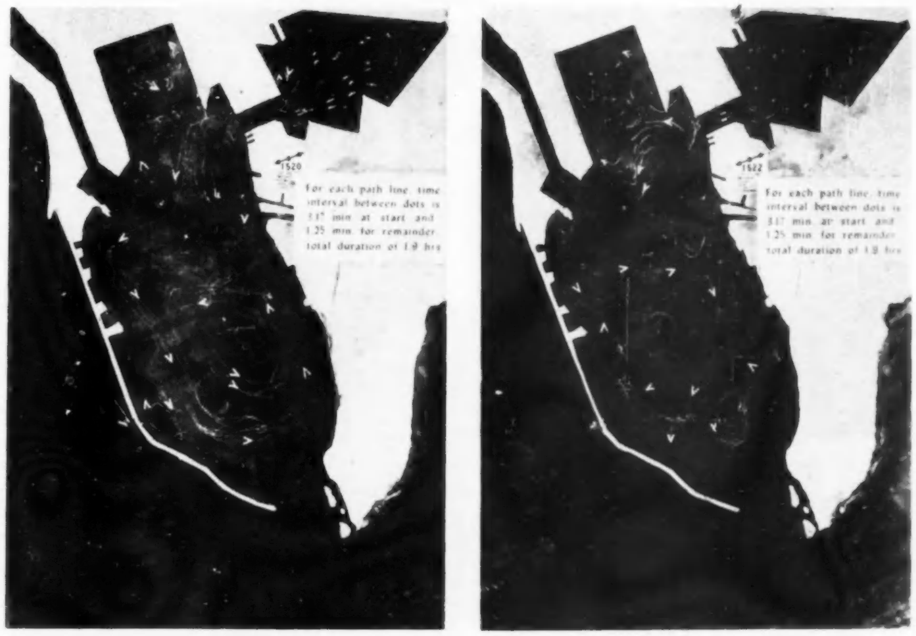
As the waves approach very small depths, such as over reefs, the wave profile is distorted and the horizontal water motion changes from part oscillatory and part translatory to almost wholly translatory. In such cases the horizontal water motion tends to be all in one direction and a considerable current is developed.

Ocean currents, generated by winds out at sea, will induce currents in a harbour by diffusion. Local winds also produce currents within a harbour and sometimes cause severe jobble disturbance. The water flowing into and out of a harbour will be affected by the boundaries, so that eddies will develop whose shape is indicative of the configuration of the boundary. The outline of the wave patterns for a given imposed wave condition as determined by refraction, diffraction and reflection, should not affect these eddy shapes, since the wave movement itself does not significantly affect the current flow, except in areas of extremely shallow depths.

TIDES

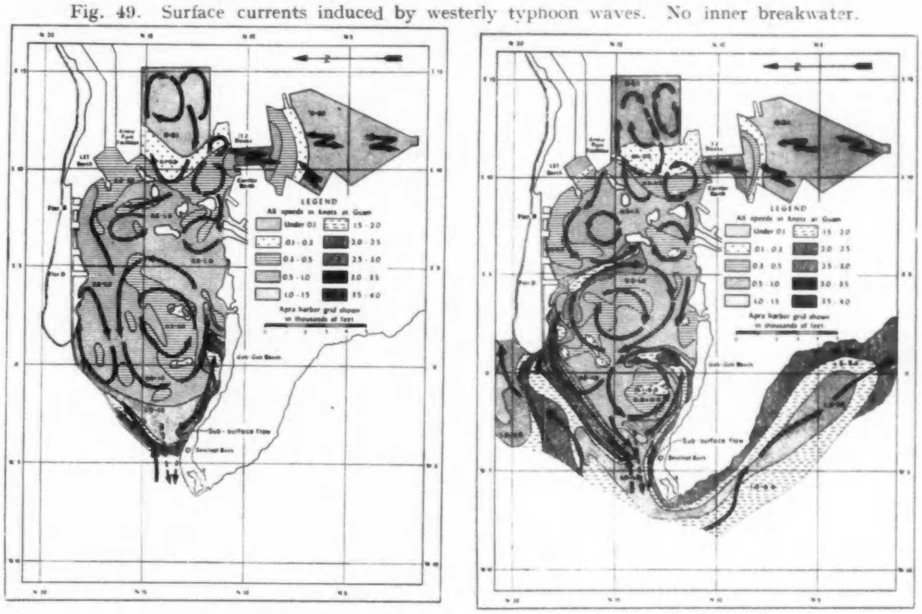
"The mean high-water interval at Apra is 7 h. 40 m.; mean range 1.6 feet, spring range (diurnal) 2.8 feet. In the harbour entrance there is a maximum flood current of 1.5 knots setting north to north-east. A maximum ebb current of 1.2 knots sets south-west. Within the harbour, currents are weak and variable, with a maximum velocity of 0.2 knot," such was the information given in "Pacific Island Sailing Directions". Tests made in the harbour gave somewhat lesser velocities of current.

Surveys and tidal records showed that the water level of the inner harbour was higher than Agat Bay about 65 per cent. of



(a)—600-foot long waves *(b)—1200-foot long waves*

Fig. 49. Surface currents induced by westerly typhoon waves. No inner breakwater.

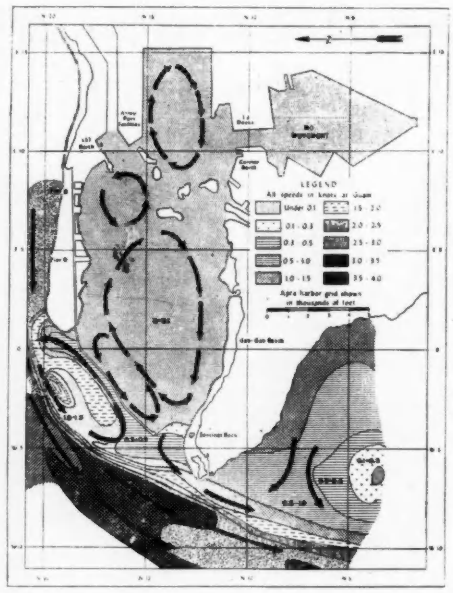


(a)—600-foot long waves *(b)—1200-foot long waves*

Fig. 50. Velocities of surface currents induced by westerly typhoon waves. No inner breakwater.

Model Studies of Apra Harbour—continued

(a)—Path lines



(b)—Velocities

Fig. 51. Effect of an E.N.E. current of 1.75 knots. No inner breakwater.

the time, and Piti channel in the north-east corner of model was higher than the adjacent ocean 35 per cent. of the time, while the water level in the inner harbour was generally 0.1 foot higher than that of the Piti channel.

The tests included the determination of the effects of a channel connecting the inner harbour to Agat Bay; and also of a channel connecting the outer harbour to the ocean near Piti causeway in N.E. corner (Fig. 5) (p. 369, April issue, the " D. & H.A."). These tests were conducted with a current of constant velocity rather than the varying one necessary to simulate the prototype. This velocity was fixed at 4 knots to assure the turbulent flow necessary for accurate modelling.

The ocean current was simulated by the use of a propeller pump situated in N.W. corner of the basin (Fig. 5) to produce a flow through a porous baffle.

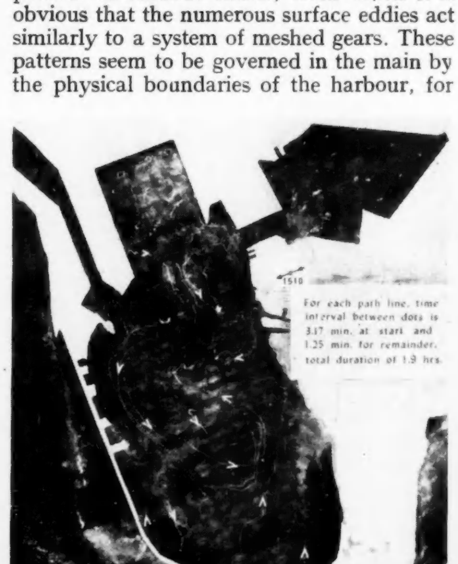
STORM AND TYPHOON WAVES.

The technique used in these tests was similar to that already described, but a good deal of visual observation in the detection of dye streaks was necessary, particularly in areas of sub-surface flow.

All the westerly storm and typhoon waves tested (10 and 30 feet high, 600 and 1,200 feet long respectively) produced a system of horizontal and vertical eddies. Reflector floats showed the traces of the former, but the latter had to be traced by dyes. Typical photographic records are shown in Fig. 49 for westerly waves of (a) 600-ft. long and (b) 1,200-ft. long. The directions of the currents are indicated by the added arrow heads, and the spacing of the dots provided the means of computing the velocity, as already described (see Fig. 45). Note the back and forth movement in the channel connecting the repair basin to the inner harbour, and also throughout the latter. They are more noticeable with 1,200 feet long waves. The diagrams of Fig. 50 (a) and (b) show the data of the above photographs and results of visual observations plotted on harbour charts, from which it is obvious that the numerous surface eddies act similarly to a system of meshed gears. These patterns seem to be governed in the main by the physical boundaries of the harbour, for although the direction of eddy movement is different in a few cases, the shape of the individual eddies is similar for both the 600 and 1,200 feet waves. The oscillatory movement in the inner harbour and connecting channel seems a rather discordant movement in the otherwise harmonious whole. A slight continuous movement does exist there, but it is overshadowed by the large amplitude of the oscillatory motion. The opposite of this condition exists in the outer harbour, where the slight oscillatory motion is obliterated by the relatively high continuous surface flow.

A considerable amount of surface current movement from the ocean to the harbour was observed at the harbour entrance in the relatively shallow water near the head of the outer breakwater. Here the wave motion tends to change from oscillatory to translatory, which produces a flow of water into the harbour. Throughout the rest of the harbour entrance the flow path is generally that defined by the eddy which moves south-west from the harbour to the vicinity of the harbour entrance, turns at the entrance and proceeds east along Gab-Gab beach. At the entrance the sub-surface water flows in opposite direction to that of the surface, indicating the existence of a vertical eddy which produces a relatively large interchange between harbour and ocean water. Speeds of about 0.75 knot exist over about one-half of the outer harbour, and in the inner harbour and repair basin never exceed 0.1 knot.

Vertical eddies are noticeable in the harbour in the area between the harbour entrance and a line approximately 3,000 feet east of it. Generally the flow pattern in the outer harbour consists of one large clockwise eddy in the eastern part of the harbour, and a counter-clockwise eddy in the western part. With 600 feet typhoon waves, these two



(a)—600-foot long waves

(b)—1200-foot long waves

Fig. 52. Paths of surface currents due to westerly typhoon waves and E.N.E. current of 1.75 knots. No inner breakwater.

Model Studies of Apra Harbour—*continued*

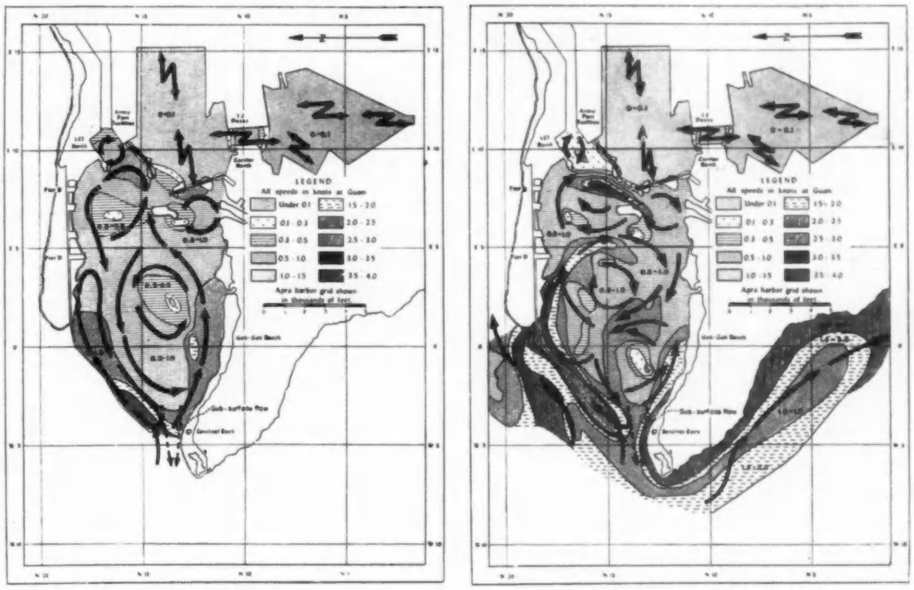
large eddies are combined into one counter-clockwise eddy, which covers most of the outer harbour. The 1,200 feet waves induce eddies with slightly higher speeds than the 600 feet waves.

Superimposed on the eddy motions was an oscillatory motion of roughly 45 minute period, which is especially apparent in the inner harbour and in the channel connecting it with the repair basin. A study of the records indicates that this motion exists throughout the whole harbour, but it seems noticeable in an inverse ratio to the eddy speeds. Results showed that the velocity of the surface current in the harbour varied directly with the height of the imposed waves, since the kinetic energy of the induced currents was proportional to the imposed wave energy. The current speeds ranged from 2 knots near the harbour entrance to 0.3 knot near the western shoal. The eddy speeds in the repair basin and inner harbour were generally in the range 0.1 to 0.5 knot for both storm and typhoon waves. The oscillatory motion in the connecting channel generally attained speeds of about 2 knots with typhoon waves.

It seems that if the lengths of the imposed waves are such that the entrance is the main control on wave energy entering the harbour, then the eddy patterns for westerly storm waves will be substantially the same for waves of lower amplitude regardless of the direction of approach. The speeds of the currents induced by smaller waves from the north-west or south-west should be approximately equal to those for westerly typhoon and storm waves multiplied by a factor equal to the ratio of wave heights times the sine of the bearing angle of the wave direction.

EFFECT OF OCEAN CURRENTS.

The effect of ocean currents of 1.0 and 1.75 knots flowing from the east-north-east over a $2\frac{1}{2}$ mile wide reach, as shown in Fig. 5, had



(a)—600-foot long waves *(b)—1200-foot long waves*

Fig. 54. Velocities of surface currents induced by westerly typhoon waves. Inner breakwater D.2.

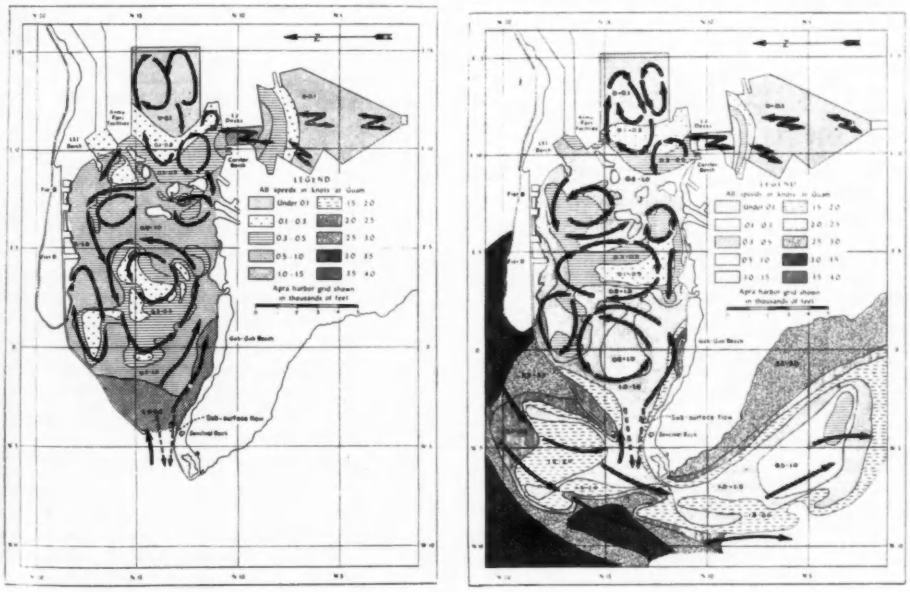
little quantitative effect upon the harbour. The ocean current speed increased to 3.5 knots one mile west of the harbour entrance, due to contraction in width when turning sharply to the south-west at the western tip of Luminao Reef. The 1.75 knots east-north-east current acting alone produces a large counter-clockwise eddy along the ocean side of the breakwater, as shown by the diagram of Fig. 51, which is plotted from photographs and visual observation. It will also be noted that there is a large but weak clockwise eddy covering the outer harbour. If the diagrams of surface currents (Fig. 50) within the harbour, due to westerly waves only, are compared with those of Figs. 52 and 53, in which westerly waves are active with an east-north-east ocean current, it will be found that the patterns are much the same but that speeds of the eddies induced by the 600 feet long waves are not affected, whereas the 1,200 feet long waves increased the speed of the eddies slightly. This indicates that the wave length is the important parameter.

EFFECT OF INNER BREAKWATER.

It is instructive to compare the velocity chart of Fig. 54, which shows an inner breakwater, type D2, protecting the repair basin, with Fig. 50, the unaltered harbour. The eddy patterns and speeds in the outer harbour are about the same in both cases, whereas in the inner basins the oscillatory motion predominates over a very slight continuous movement. The currents do not exceed 0.1 knot, except in the connecting channel. It seems, therefore, that the only significant effect of the addition of the breakwater is to restrict slightly the circulation which was already slow in the inner basins with the unaltered original shoals.

ARTIFICIAL CIRCULATION CHANNELS.

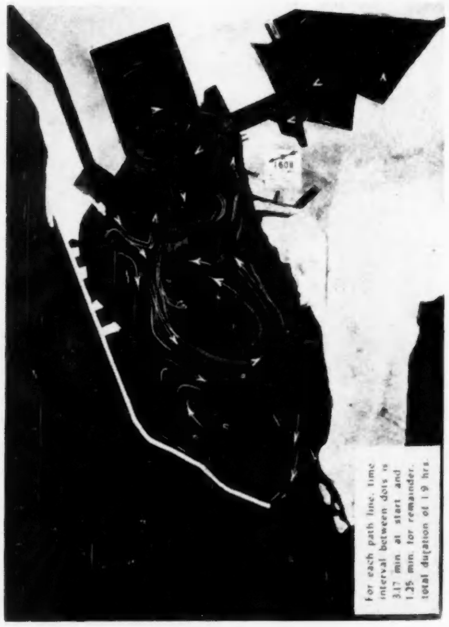
Included in the investigations was the study of the effects on the harbour circulation system by the construction of a channel from the extreme south end of the inner harbour connecting the latter with the ocean in Agat Bay (Fig. 5). A constant 4 knot current flowing through this channel between the harbour and the ocean produces a circulation path (Fig. 55) through the harbour varying from 1,000 to 3,000 feet. The harbour-ocean circulation produced is limited to a relatively narrow main current flanked on either side by eddies which move at speeds approaching stagnation over large parts of the harbour. The circulation path seems to be controlled by the outer



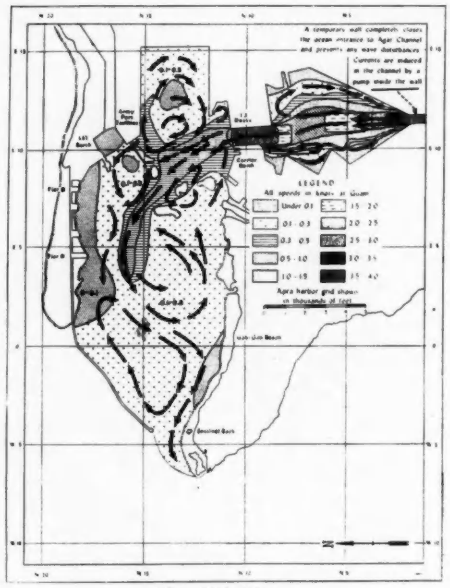
(a)—600-foot long waves *(b)—1200-foot long waves*

Fig. 53. Velocities of surface currents due to westerly typhoon waves and E.N.E. current of 1.75 knots. No inner breakwater.

Model Studies of Apra Harbour—continued



(a)—Path lines



(b)—Velocities

Fig. 55. Constant southerly flow in Agat Bay Channel. No inner breakwater.

harbour entrance. In areas adjacent to the main circulation path, the water moves in eddies at speeds from zero to 0.5 knots.

The introduction of storm waves through the harbour entrance, the screening of Agat bay channel entrance from the sea, and a constant 4 knot current caused to pass through the channel, reduced the wave-induced eddies in the outer harbour. The 45 minute oscillation was again noted throughout harbour.

SUMMARY.

Summarizing the results of the many tests, it appears that whether by waves or flow, in a circulation channel, the effect is to form a series of horizontal eddies which conform to the shape of the boundaries in which they exist. The general picture which makes this clear is shown in Figs. 56 and 57. Ocean currents have no significant effect on the circulation inside the harbour. Waves alone, as we have seen, generate horizontal eddies in the depths of the harbour and vertical eddies near the entrance. These eddies not only restrict the direct interchange of harbour and open sea water, but have the effect of mixing harbour waters. The main mechanism of water change, ingress and egress, is due to the vertical eddies at the entrance; even under the most severe storm conditions the inner harbour waters remain more or less stagnant.

The opening of the Agat Bay channel, although creating a current of appreciable width and speed through the harbour, does not give results efficiently effective in the inner harbour to justify its construction, particularly in view of the fact that the current flow used in the tests was above the maximum and endured for a greater period of time than would actually take place in nature. The difference in ocean-harbour levels represented by the 4 knot current of of the test is 0.70 foot, whereas the tidal variations actually limit the water levels' difference to 0—0.18 foot. If the two proposed channels, Piti to the north-east, and Agat to the south, were both opened, the mixing of the sea and harbour waters would be increased, but the circulation would be restricted to the connecting line of the entrances. Tests made by the installation of siphons to replace the inner harbour waters showed greater general improvement than the use of channels.

Local wind effects were not studied, but in certain circumstances they would modify the surface eddies, for it was observed that in some areas particles on the surface circulated for days on end in the doldrum of a slow eddy. In the harbour entrance a current of 1.2 knots is induced by the ebb and flow tide.

From the model studies it was concluded that:

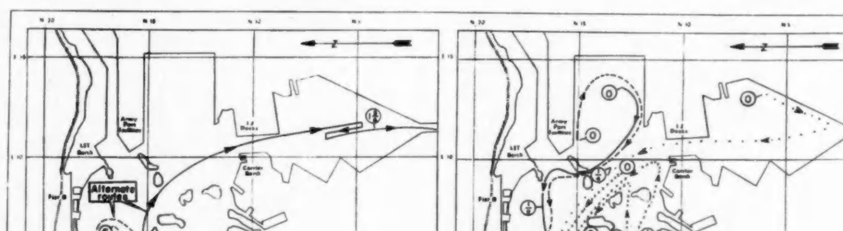
(1) Uniform circulation conditions do not prevail over the entire basin under any of the imposed conditions. The current-velocity charts indicate the location of stagnant areas (speeds under 0.1 knot) and active areas. Most of the repair basin and inner harbour are typical stagnant areas even under the most severe storm conditions, while the areas in front of the Gab-Gab beach and along the south-west arm of the breakwater are typical active areas.

(2) An inner breakwater does not affect significantly the circulation anywhere in the harbour.

(3) A channel connecting the inner harbour to Agat Bay is not capable of sufficiently increasing the circulation over a large enough area to warrant its construction; in fact, although combinations of channels could be devised to improve the circulation, such as the Piti channel to north-east and the Agat channel to the south, the effect would only be localised, since the control is exercised by the effect of the entrances in orienting the circulation path.

(4) Properly located pumping stations would produce adequate circulation throughout the harbour.

(5) The inner harbour, which is the most used, will be most polluted from the foul waste of the berthed vessels, and in this basin stagnant conditions exist, yet the Terminal Island harbour, which is about the same size as Apra inner harbour, functions satisfactorily even with the added wastes from canneries in the area. It is, of course, understood



(a)—Predominantly northern flow (b)—Predominantly southern flow

Fig. 56. Variable flow in tidal channel as it affects entire harbour as shown by the movements of a floating particle.

Model Studies of Apra Harbour—continued

that such waters would not be wholesome for human use. Should conditions prove insufferable in the future, the construction of Agat Bay channel would relieve the nuisance to some extent. The most definite solution for the removal of foul waters is the provision of suitable pumping plant in the natural collecting areas of stagnant water.

GENERAL CONCLUSIONS.

The use of distorted models for studying shallow water wave phenomena is always suspect, since prototype shallow water waves may be distorted by bottom refraction effects not present in a distorted model. If the bottom of the prototype area is relatively flat or only gently sloping in the direction of the wave advance, then the effect of bottom refraction on shallow water waves is only to shorten the wave length without otherwise distorting the wave crests. In such cases, model distortion is not too serious, since the model wave patterns will be parallel to the prototype, hence the model energy distribution will approximate closely prototype conditions. With the exception of the U-shaped entrance channel, Apra harbour fulfils these conditions. Thus the distorted model 2 : 1 used for the outer breakwater studies does not affect the validity of the results.

The model used for the study of water surface disturbance within the harbour was undistorted and therefore all questions regarding the effects of model distortion were eliminated. However, it was advisable to give careful consideration to the adequacy of the sampling technique and the damping, or spending, of the disturbed water surface in the model compared to that of the prototype.

The water circulation data are so complete that, when the sanitation data become available after use, it should be possible to assess with accuracy the pollution problem.

Briefly, the main conclusions which emerge from these studies are:

(1) The harbour entrance, a natural channel, exercises almost complete control on the magnitude and direction of the wave disturbances entering the harbour other than over Calalan Bank. The topography of this channel is such that waves approaching from any direction in the S.W.-N.W. quadrant are altered by bottom refraction and enter the harbour with curved wave fronts on an approximately east-west axis.

(2) The entrance channel at the −45 feet contour has almost parallel sides to the north and south; as a result, the protection provided by a breakwater constructed on the Calalan Bank, with its toe at elevation −45 feet, is insensitive to exact breakwater alignment. Any small performance differences between breakwaters constructed according to this general plan are due entirely to the small differences in entrance width, which are possible with different alignments.

(3) The dimensions of any breakwater head are so small compared to a wave length, that the termini do not produce appreciable wave diffraction effects, therefore the shape of the head does not affect the waves entering or the wave disturbance within the harbour.

(4) The water depths over the reef to the south of the harbour entrance are so small that the shoal acts as an effective barrier to wave energy transmission. There is thus no need for a stub breakwater.

(5) The exact alignment of the breakwater on Calalan Bank is important in determining the liability of the breakwater to overtopping and damage. Alignments along the harbour side of the bank are most favourable, since the resulting shallow water region to the seaward face of the wall dissipates part of the wave energy.

(6) The disturbance pattern in the outer harbour shows calm and active areas. The greater part of the central area is active and will therefore provide poor anchorage during major storms.

(7) The theoretically predictable benefits to be obtained from orienting and placing a harbour entrance to obtain maximum expansion of entering wave crests was verified in the study; reductions of 50 per cent. disturbance were shown to be possible with an entrance through Luminao Reef.

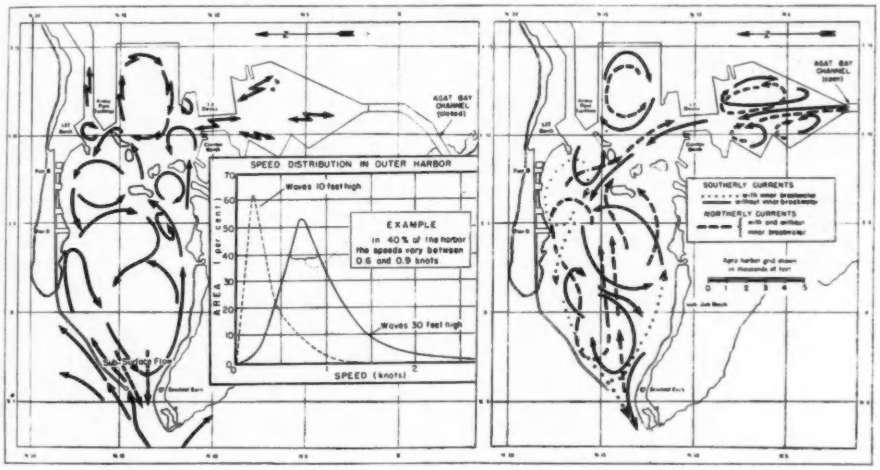
(8) The disturbance pattern in the outer harbour is considerably affected by wave reflection from Jade, southern and western shoals, which isolate the outer harbour from the repair basin. These shoals also provide protection to the usage areas and render the construction of an inner breakwater economically unnecessary.

(9) The tests showed that Apra Harbour is liable to resonant oscillation at a number of periods from 1 to 30 minutes. The potentially dangerous periods are approximately 6.5, 4.4, 3.8, 2.9 and 1.9 minutes, with resonant amplication factors as high as two and horizontal water velocities as high as one-quarter knot per foot of imposed wave height at specific locations. The repair basin is particularly active during resonant oscillation and within this area the east shore is least disturbed. The inner harbour is little affected for periods less than 3 minutes and is relatively quiet for all periods, with the north-western docking areas being the most disturbed. Most of the docking facilities in the outer harbour are little disturbed by resonant disturbances, excepting the L.S.T. landing, in north-east corner.

(10) The water circulation in Apra Harbour is due primarily to the action of waves entering the harbour, the effect of ocean currents being negligible. The velocity of the currents induced by ocean waves is directly proportional to the wave height.

Despite the lengthiness of this review it was impossible to cover all the details of the original report with completeness; nevertheless it is hoped that the chosen examples of the various tests have been ample to show the main features of this elegant series of reduced model studies of harbour hydrodynamic conditions. One notes two very important qualities of Dr. Knapp's work; the lucidity of his methodical approach, and the modesty of his conclusions. The original voluminous report showed that all tests were analysed, checked and rechecked exhaustively to eliminate, or isolate, casual or incidental extremes, and mechanical and observational errors, with the result that many of the patterns are truly seen to be universally valid and applicable to harbours everywhere.

R. R. M.



(a)—Westerly typhoon and storm waves, 600 and 1200 feet long *(b)—Southerly and northerly currents in Agat Bay Channel. No waves*

Fig. 57. General circulation patterns.

Improvements at Stockton-on-Tees

Details of Quay Extension and New Warehouse

By GILBERT COWAN, A.M.I.C.E., M.Inst.Mun.E., A.R.I.C.S.

A new Depôt which is probably the first of its kind to be specially designed and built in this country for handling goods by the fork lift truck and pallet system, has been opened at Stockton-on-Tees.

The provision of this facility affords an interesting example of co-operation between a Municipality and an industrial undertaking. Even before the war ended, negotiations were taking place between the Corporation and Messrs. S.P.D. Ltd., the distributing and warehousing organisation of the Unilever Group, and it was by dint of keen and persistent advocacy, in which useful co-operation was forthcoming from the Ministry of Transport, that the Corporation, shortly after the end of the war, obtained authority for the prosecution of the scheme at a total cost amounting to approximately £117,000.

The existing quay was extended by 328 lineal feet with a berth dredged to give 16 feet of water at L.W.M.O.S.T. and a berth width of 50 feet from the face of the sheet piling.


Work in progress on Quay Extension, view from existing Quay.

The face piles were driven through water bearing to hard red sandstone and were 67-ft. long in No. 5 section larssen sheet piles with 10-in. x $\frac{5}{8}$-in steel plates welded on centrally over a length of 30 feet.

The steel sheet piled face is held back by pairs of $2\frac{3}{4}$-in. diameter tie rods at 11-ft. centres attached to the face piling and bents of No. 3 section larssen piles. The load is distributed over these piles by means of steel channel sections and the tie rods are treated with bitumastic compound, wrapped in hessian and surrounded with 6-in. mass concrete and are sited 15 feet below floor level of the warehouse.

The crane track sited near the face of the quay is 12-ft 6-in. gauge and is carried on reinforced concrete longitudinal and transverse beams supported by No. 3 section larssen box piles 65 feet long.

To avoid settlement the inner rail of the crane track connecting with that on the existing quay is supported on 9 No. 17-in. diameter reinforced concrete bored piles 40 feet long.

The steel sheet piled face to the quay is protected with 12-in. x 12-in. elm fenders which are held in position with steel cleats attached to the face of the piling and 2-in. elm rubbing pieces are in turn attached to the fendering to take wear and tear and avoid as far as possible damage to the fendering itself.

The quay extension abuts on to a battered face at the downstream end of the existing quay and the connection is made by means of 12-in. x 12-in. greenheart piles with 12-in. x 6-in. greenheart walings.

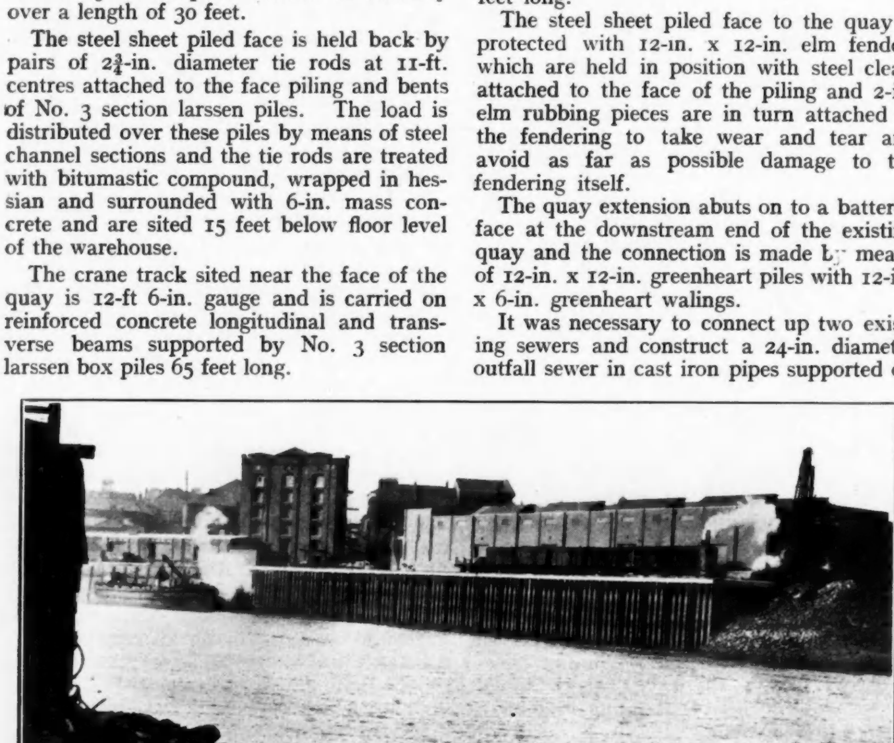
It was necessary to connect up two existing sewers and construct a 24-in. diameter outfall sewer in cast iron pipes supported on a reinforced concrete raft and precast reinforced concrete piles.

The sewer outfall was passed through a sleeve attached to the face of the sheeting by means of a short length of 24-in. diameter steel tube and the joint between the sleeve and the tube was rendered water-tight with a bitumastic packing. This provision was considered necessary to allow for any deflection which might in future take place in the steel sheeting without damaging the sewer outfall.

The whole of the quay extension and also a section of the rail tracks on the landward side of the warehouse have been finished with a 6-in. reinforced concrete deck flush with rail level.

One rail siding on the riverside and five sidings on the landward side of the warehouse are provided, the latter giving standage for approximately 100 trucks.

External lighting, fencing, a water supply and ships' lighting are provided to the quay.


General view of Quay Extension and Warehouse from the south bank of the River Tees.

Warehouse

The warehouse is constructed as a steel-framed building with 12-in. brick cavity walls carried on steel bressemers connected to the stanchions supporting the roof trusses.

The warehouse includes an office block at first floor level, an entrance hall, a foreman's office, messroom, re-coopering room, lock-up room and lavatory accommodation at warehouse floor level; the warehouse itself being 220 feet long by 88 feet wide.

The tie beam level of the roof trusses, which have an effective span of 90 feet, is 17 feet above the floor of the warehouse to allow the stacking of goods on a palletised system to a height of 16 feet and the stanchion bases carrying the trusses are supported by 12-in. by 12-in. precast concrete piles varying in length from 20 to 30 feet.

A 6-in. reinforced concrete floor is provided in the warehouse with a patent "Plastona" granolithic finish and the floor, owing to the sloping site, has had to be laid on a considerable depth of filling and is designed to carry a load of 7 cwts per square foot.

Improvements at Stockton-on-Tees—continued

A 10-ft. wide loading bay runs the whole length of the warehouse on the riverside and an additional loading bay, varying in width from 5 to 10 feet and following the line of the nearest rail siding, is provided on the landward side, access to the warehouse floor being gained from these bays by means of 10-ft. by 10-ft. openings fitted with roller shutters.

At the front of the building, a loading bay within the limits of the warehouse and protected by a canopy, is provided for outgoing goods, this opening being closed by two roller shutters 14-ft. 6-in. high and approximately 31-ft. and 21-ft. wide respectively.

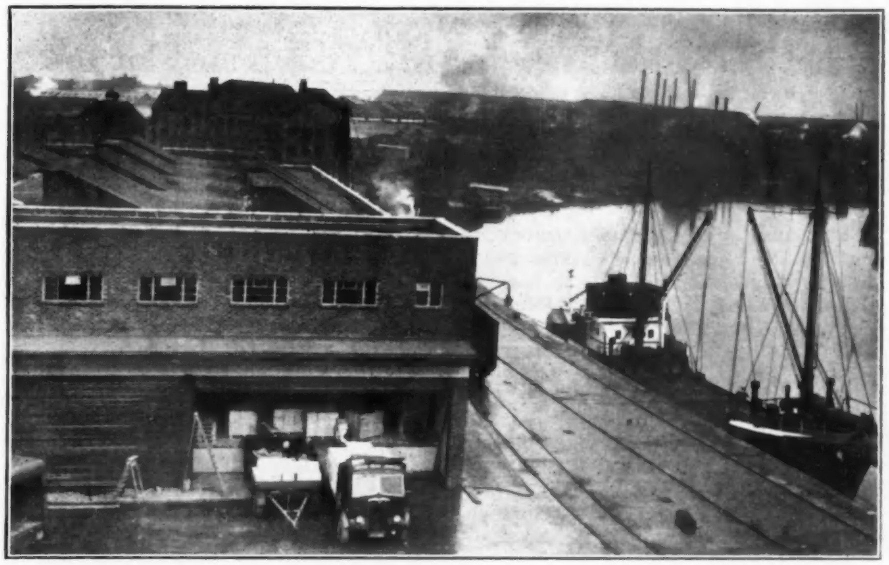
As already mentioned, the external walls of the building are 12-in. cavity walls above plinth level which is set approximately 3-ft. above the level of the loading bays and below that point a 16-in. solid brick wall has been provided.

The best possible architectural effect has been obtained by means of rustic brick facings pointed in white cement and natural lighting to the main entrance at the side of the building is achieved by glazed entrance doors and three vertical glass brick panels, which at the same time provide an attractive architectural feature.

Windows to the warehouse are included in the gable and side walls, the cill level being at 18-ft. above warehouse floor and on the south side glass bricks are substituted for metal casements to achieve the best possible thermal insulation.

The roof is covered with Ruberoid steel decking and is of penthouse design with north lighting only.

In order to ensure as far as possible that the temperature in the warehouse will never rise above 65 deg. F, a system of Sturtevant impulse fans with directional cowls are installed in the side walls and seven extract fans in the penthouse gables, thus providing three complete air changes per hour.



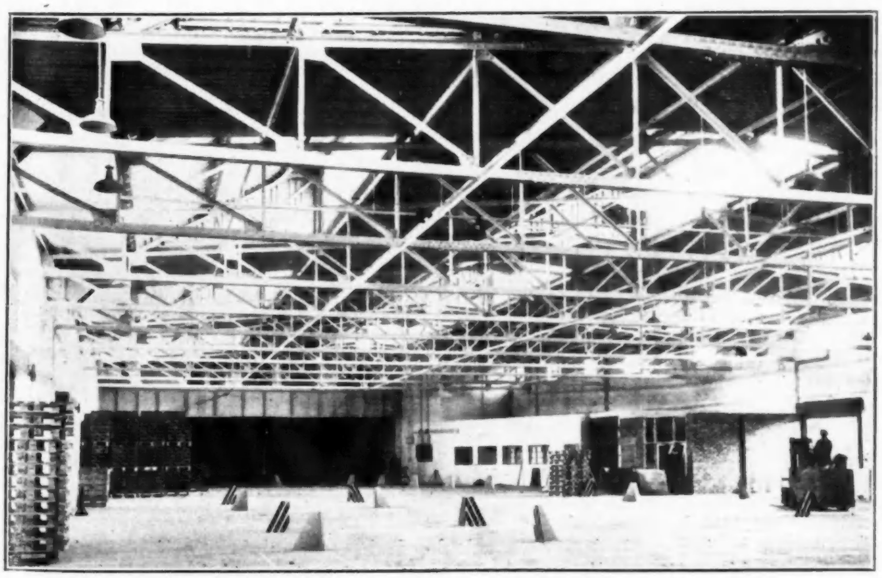
View of Warehouse showing Pent House roof construction and Office Block and overloading bay at the output end of the building.

The entrance hall is finished to dado height in Terrazzo and the access to the office block at first floor level is by means of a corridor overlooking the warehouse for inspection and supervision purposes. The floor in the office block is covered with a Marquetone finish.

Every effort has been made to provide the most up-to-date lighting system possible in the warehouse itself by means of fluorescent strip lighting to the corridors between the stacking bays, and tungsten filament lamps over the bays themselves. On test this sytem gave an intensity of light at floor level of 11 foot candles.

The warehouse has two rail-connected loading bays, one facing the quay and the other for emergency use, on the landward side, the rails being sunk into the concrete surface so as not to impede the access of road vehicles, which are dealt with at a loading stage near the front entrance. The Depôt is thus served by rail, road and water, as the goods can be handled direct by travelling crane between ship and warehouse.

Engineering Works. The whole of the works in connection with the Quay Extension and Warehouse were designed by and executed under the supervision of the Borough Engineer, Mr. G. Cowan, A.M.Inst.C.E., M.Inst.Mun.E., A.R.I.C.S., the main Contractors being Messrs. W. G. Turriff Ltd., of Leamington Spa.



Interior of Warehouse looking towards the output end.

Errata

Model Studies of Apra Harbour

The description given in the April issue of "The Dock & Harbour Authority," p. 369, of the construction of the mould boxes for the model contours is not correct. Actually a single 4 x 4 feet square sheet of plywood only was used for each entire mould. All the contours at 15 feet vertical intervals were traced on a sheet and then, as though constructing a jig-saw puzzle, a fine saw cut was run through each trace.

Each separate piece was then placed in the mould box at the correct level on step cut vertical ribs so that there was no overlap, in other words, the plan view was identical with the original plain sheet except that thin saw cut gaps replaced the pencilled contour traces. The gaps were so slight that very little cement was lost on pouring. Dr. Knapp has since informed our Reviewer that in the future he would use, in similar circumstances, $\frac{5}{8}$-in. thick plywood to obtain $\frac{1}{8}$-in. overlap at the joints.

In the July issue of the Journal, p. 82 in the line first above expression (1) the word model should read nodal.

Port Working in the United Kingdom

Second of Three Articles contributed for the New Education Scheme for Port Workers

(By a Special Correspondent)

The second article, specially written for this Journal in connection with the Education Scheme for Port Workers, deals with the following topics, and as with the first article, a synopsis is given at the beginning of each sub-heading setting out the main points covered in the ensuing paragraphs.

1. Loading, discharging and berthing of vessels.
2. Part played by ports in transhipment, entrepôt trade, and in marketing and warehousing.
3. Port layout to facilitate terminal operations.
4. Road, rail and inland waterway connections with ports. Lighterage facilities.
5. Equipment and appliances. Passenger traffic working.
6. History of dock labour from the beginning of Trade Union Organisation in 1887.
7. Port labour, methods of payment. The constitution and functions of the Dock Labour Board.
8. Industrial relations.

Owing to limitations of space, however, it has been found necessary to print the article in two instalments, and accordingly, this issue will deal with items 1 to 4 and items 5 to 8 will appear in our October number; the publishing of the third article in the series being postponed until November.

1. Loading, Discharging and Berthing of Vessels.

The port as a link between the various forms of transport. The traffic flow. The type of cargo as it affects allocation of a suitable berth. Passenger liner, intermediate and cargo liner, tramp, short sea trader and coaster. Bulk cargo, general cargo, petroleum cargo, hazardous or explosive cargo, and the part cargo. Overside discharge and/or loading in open sea, harbour or river estuary. Quay discharge and/or loading in dock or open basin.

The student should realise that ports are links and not instruments of transport. They belong to neither road, rail, canal, nor sea but depend for their smooth operation on transport units using all of these. Ports are points where changes in the method of conveyance occur, and unless skill is used in their design and layout conditions may arise where the natural disparity between the carrying capacities of the sea transport unit and the land transport unit create difficulties of organisation. The efficiency of any port depends upon the extent to which the rates of flow in either direction of the complementary forms of transport can be coordinated and equalised at the actual exchange point.

It is unfortunately rare that traffic inflow and outflow are maintained in equilibrium throughout the year. Storms, seasonal changes of demand and supply of different commodities (e.g. the softwood timber season in U.K. is, owing to certain loading restrictions laid down by the Merchant Shipping Act 1906, from 17th April to 30th October in any year) fluctuations in commodity price levels, varying and competing points of origin causing diversions and changes of destination, all militate against a steady and planned flow of traffic in either direction. The most that can be done by the port management is to segregate the various trades and carrying units into areas or berths designed as far as possible to cater economically for units of equal or nearly equal size, so as to keep unprofitable effort within reasonable limits. Thus two coasting vessels each 200-ft. long could quite easily be handled at a berth designed to accommodate one 500-ft. ship, but this would be uneconomical and would not be attempted unless no other berth offered in the port, for the coasters having considerably less draft than the larger vessel, they would not utilise fully the expensive facility of draft, and if cranes were provided they would probably be of considerably greater outreach and capacity than would be necessary to deal with a coaster's cargo. Also any transit shed space provided would not be adequately used, being designed to cater for a vessel of larger capacity than both coasters together. Generally speaking the capital expended would not be used to best advantage.

The primary importance to a shipowner (and therefore to a port owner, their interests here being indentical) of a cheap and speedy turnround of his vessel has been stressed in the first article.

Usually a "charter party" (the legal document embodying terms and conditions under which a shipowner hires his vessel to another owner or cargo owner) stipulates that the ship must remain "always afloat" throughout the period chartered. The effect of this warranty (a breach permits the shipowner to cancel the charter party and sue for damages) is that the vessel must use a berth giving flotation at all states of the tide. It is usual to allow a minimum depth of at least a foot below lowest tide levels (preferably more) over the permissible draft at which a vessel can be accepted either for discharging or loading alongside a quay, etc., or in open waters. In places specially designed and levelled river wharf "alongside" berths surfaced with chalk (if inclined to silt) exist where smaller vessels (or those specially stiffened) can take the ground without straining.

Some ports make use of a dredged trench or pocket in the river bed (at a site where the tidal current runs true both for flood and ebb throughout its length) of dimensions slightly deeper, wider and longer than the deepest drafted vessel to use it. Permanent moorings with buoys are placed at either end of this dredged area and the ship moors to them lying fairly in the prepared berth. Barges or coasting vessels alongside work cargo between themselves and the ship using the ship's cargo working gear.

Such berths can be provided fairly cheaply and if both sides of the cargo vessel can be worked simultaneously are cheap and speedy working from the cargo standpoint. They are popular in certain Continental ports, where barge and coaster traffic preponderates.

The next cheapest class of accommodation to provide is the river wharf, with flotation for barges alongside working to and from vessels out in the stream. The deep water river wharf, i.e. for accommodating afloat an ocean-going vessel is much more expensive and must be designed to use to the full existing natural advantages. Thus the high banks of some northern rivers of the United Kingdom enable loaded coal trucks to be run down to colliers, lying alongside coaling jetties or staiths, by gravity.

The foregoing types of accommodation are provided in ports where bulk and raw materials are the principal cargoes handled and there is little demand for deep water basins and docks. The general layout of an enclosed dock has been given in the first article of this series. A deep water basin is similar, except that as there is no gate or lock at the entrance the tide has access to it at all times. Enclosed docks and basins are the most expensive type of port accommodation, usually only to be found in the older and more highly developed countries handling import and export cargoes of value.

A "stowage plan" (made out at the port or ports of loading) a diagrammatic longitudinal section of the ship, showing the position of all cargo in the holds, is forwarded to the Traffic Department of the Dock or Port Authority well before the ship's arrival at the berth, in order that it can be studied, and a convenient berth allocated.

It has been calculated that one-third to half a foreign-going vessel's running expenses are represented by port charges and handling costs. Coasters, owing to longer time spent in port,

Port Working in the United Kingdom—continued

occupy only about one-third of their total operating time at sea under full power (i.e. earning freight). Hence the need for a careful selection of a berth.

A passenger liner may use a specially designed terminal such as that at Southampton or the floating landing stages at Tilbury (London) and Liverpool. Passengers can be quickly dealt with at these and kept away from busy dock-side berths. Special trains can be run to and from the ship's side especially for them, but these standing on one quay may disrupt operations at adjoining quays until cleared. Small numbers of passengers may board or land at a dock berth, but experience has shown that special facilities provided outside and preferably downstream of the port's cargo area where passenger ships can berth immediately on arrival or just before sailing to take passengers direct on board, are best. The vessel is saved heavy dues, and the risks of passing through congested waters when only calling to pick up passengers.

An intermediate vessel or cargo liner, if a regular caller at the port, usually proceeds direct to the berth customarily used by vessels of the line. Such berths may be "appropriated" or leased to the Company by the Port Management on condition that the Shipping Company guarantees reasonably continuous usage, for the Port Authority must see that its available berths are fully used. Customs may be involved in berthing arrangements when dealing with cargoes such as tea, tobacco, etc., which require "bonded" accommodation. Usually a considerable amount of trade in bonded goods has to be guaranteed before Customs will permit such accommodation.

Tramp vessels present berthing problems, as they come and go to no regular schedule, but are often chartered to load seasonal cargoes in full ship loads. On receipt of advice of arrival from agents or brokers, the ship is directed to the most convenient and unallocated berth available, but this must be suitable to deal with the cargo as shown on the Stowage Plan. Thus a full load of soft timber needs considerable stacking area behind the quay, the normal transit shed and general cargo berth layout being quite unsuitable.

The short sea trader or coasting vessel accustomed to arriving at any state of the tide usually proceeds to its Company's own river wharf or mooring to berth, but if accommodated in an enclosed dock at an "unappropriated" berth, regard must be had to the nature of the cargo to ensure the best use being made of the facilities provided. In the case of an older port having smaller and shallower dock or wharf accommodation (often relics from its past trade) this may be allocated and used.

Petroleum in bulk, explosives, and certain hazardous cargoes have by law to be allocated special areas where ships carrying such goods can be dealt with. In most ports berthing facilities for such are provided well away from populous centres.

The Petroleum (Consolidation) Act lays it upon port authorities to issue and enforce byelaws governing the handling and carriage both in ships and barges in and out of the port area, of petroleum products having a flashpoint below 73° Fahrenheit. The Act also stipulates that the port authority designate areas in which such low flashpoint cargoes may be handled within its jurisdiction and shall name a responsible official whose duty it is to see that its byelaws are observed. Loaded bulk petroleum tankers are normally not allowed to proceed any great distance within the confines of the port, but must remain and be handled downstream of a defined limit.

Similarly the Explosives Acts lay upon port authorities the issue and enforcement of byelaws governing the handling, carriage and stowage of all explosives brought into and out of the port. These bye-laws cover both ocean-going vessels and harbour craft and barges. Ships carrying the more dangerous explosives (which are defined and are being continuously added to by the Home Office regulations), detonators, etc., may not proceed any very great distance within the port. Heavy penalties are provided for infringements of both petroleum and explosives byelaws.

Hazardous cargoes, such as Carbide of Calcium, mineral acids, celluloid, etc., may also be dealt with under codes of byelaws. All ports issue for the guidance of shippers and shipowners, the regulations under which they are prepared to handle, with the approval of the local Fire Offices Committee on their docks or river wharves, cargoes of this type, subject to suitable safeguards.

If any question arises as to the observance of the byelaws or the handling of such cargoes, an Official known as the Dock or Harbour Master is unsually designated under the byelaws as the responsible official. He is responsible, having knowledge of the port, regard to the safety of the harbour and all ships therein, and familiarity with ships and shipping generally, for the observance by all persons of the regulations laid down, and authority is given him to board all vessels within the port area to see if these are being duly carried out.

For part cargoes some U.K. ports provide a deepwater river wharf or jetty seaward of the dock or port area. Here the dues charged on the ship will be less than if the vessel was dealt with at an enclosed dock. River dues are considerably less than dock dues and use of a deep water general cargo jetty for small parcels represents a saving in time and costs. Special rail or barge connections are provided, with jetty cranes and local temporary storage facilities.

Where no deep water accommodation is provided or there is inadequate depth alongside an ocean-going vessel may lie off shore or in a part of the harbour or estuary to which she can safely get, cargo being discharged or loaded overside from barges (working both sides if possible) using the ship's cargo handling gear. The barges are discharged or loaded at shallow water quays or barge jetties, close to and connected with the shore.

This method of handling is expensive, very susceptible to weather conditions, mechanical delays and breakdowns (of tugs, etc.), but has the merit that that most expensive of facilities to provide and maintain, viz.: deep water accommodation alongside, is unnecessary. Ports serving undeveloped areas abroad use it freely, but some U.K. estuaries capable of floating oceon-going vessels, and connected with canal systems handle cargoes in this manner to and from river and canal going craft.

Systems of discharge or loading in dock or at alongside berths vary, expediency and custom entering strongly into the picture here. If cranes are provided of modern design and capacity, these may be used, but if not, the shipowner may decide to use the ship's own derricks and winches, the commonest method being to operate the runners from two derricks and two cargo winches, free ends joined together with a ring carrying a cargo hook and swivel. This method is known as "Union purchase" (in America "double burton"). Every quay operator has his own ideas as to how certain cargoes should be handled (if he has not his foremen will have) and it is extremely difficult to introduce a new method contrary to the established practice of a port. There is scope here for research as to which really is the best method of handling any particular type of cargo.

What is known as the "Custom of the port," which may be defined as any particular port's normal (often unwritten and time honoured) methods of cargo handling, its manner of stowage in warehouse or shed, its systems of payment and methods of marketing or otherwise dealing with a certain commodity, is an important factor.

Many of these "customs" are to-day open to criticism from the standpoint of efficiency and economy, but, being known to all and sundry connected with the trade in the commodity affected (and often budgeted for in the economy thereof) are allowed to persist.

2. Part Played by Ports in Transhipment, Entrepôt Trade and in Marketing and Warehousing.

The function of the transhipment port. The function of the entrepot port and its place in the national economy. The facilities afforded by entrepot ports for the marketing and warehousing of goods.

The function of the transhipment port is to provide facilities for the easy and cheap interchange of cargo from ocean going vessels into coasting, river, or canal craft capable of proceeding coastwise or to towns and river ports on the waterway system connected to the port. Sometimes, due to high money values in another country (reflected in high port charges) the larger ocean-going vessel, finding itself with insufficient cargo to be landed to justify its incurring heavy port charges, may proceed to a cheaper foreign

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port, and the cargo off-loaded may be carried on its final destination in a coaster, whose port charges will not be so heavy as the original vessel. The same may apply to a port where a shipowner considers he will get a quicker turnround, which to him may mean less port expenses.

Transhipment of goods, although it provides employment for the port and transport community of the town, does not otherwise contribute to the general economic welfare, since the goods dealt with only pass through and are not changed in character (i.e. manufactured) although they may be dealt with in the port area superficially by re-packaging, etc.

The entrepôt port is a port of destination both for ships and goods with warehouses and commodity markets and an active mercantile community. Merchants abroad know that they can send raw or partly manufactured materials consigned to their representatives residing locally, who will arrange with the port authority to discharge the goods and store them against sale by sample in the commodity markets of the town, or for disposal by Public Auction. Instructions may be given for samples (bales of wool, mohair, cotton, etc.) to be exhibited in a suitable place (often in the dock area) for inspection by potential buyers. In the case of partly damaged cargo, orders may be given for the damage to be surveyed prior to making a claim, and later instructions may be issued for the undamaged cargo to be separated for sale. When sold the port staff will, on instructions arrange for the passing of Customs "entry," payment of duty and will deliver the goods to the buyer on receipt of the usual documents.

Entrepôt ports attract persons dealing in particular commodities around them and port managements may employ expert staffs to carry out merchants' instructions as regards sorting, grading, blending, lotting, etc., goods before offering for sale.

Wines, spirit and tobacco are handled under bond and in these days of high Customs duties the importer pays only on the quantity of which he wishes to take immediate delivery. Since some bonded commodities mellow by keeping, the port authority may arrange for the importer to leave his goods warehoused for a small weekly charge for rent made by the Dock Authority, rather than pay the duty on the whole parcel and store on his own premises.

Again operations on bonded goods, such as bottling and blending wines, bulking and blending teas, are often carried out by dock or port warehouse staff to merchants' orders before duty is paid on them and delivery taken.

Sometimes damaged cargo has to be prepared ready for sale, the damaged portions being taken out, or for reasons of trade a bulk cargo has to be bagged, or another cargo rebagged so that all evidence of its origin is removed, cases relabelled, or re-portmarked on re-sale or transhipment. All these operations are daily performed at mechant owners' request and expense in an entrepôt port.

To assist importers, merchants and others in their dealings in commodities many dock authorities issue (against surrender of the Bills of Lading to them) what is known as a "Dock Warrant." Possession of this document is equivalent to holding a bill of lading and commercially and legally it is a document of title, being recognised as evidence of ownership of the goods named, and that these are held by the Dock Authority at the disposal of the holder. As with a Bill of Lading, it can be lodged with a bank against a loan; it can be transferred from one owner to another (for value received) by endorsement and delivery. Delivery of the goods named can be had by lodging the warrant with the dock authority in whose warehouses the goods are held.

All the activities mentioned above mean larger warehouses in and around the port area, sometimes of a special design (e.g. Tobacco warehouses in London, cotton "safes" at Trafford Park, Manchester, etc.). Warehousing is a source of revenue to a port, but it has certain responsibilities to owners of goods for managements must ensure careful and safe storage, freedom (as far as possible) from attack by vermin, weather damage, etc.

Warehousing at the port also suits the provincial importer of goods who arranges for his goods to be held in the warehouses until he is ready to take delivery at his inland works or factory. It also assists the merchant speculator who buys against a rise in market prices, and holds the goods until this occurs.

3. Port layout to facilitate terminal operations.

Brief description of the layouts for the bulk handling of imported coal, grain, frozen meat, provisions, bananas and sugar. Timber cargoes. Handling of bulk oils. The orthodox layout for the handling of general and export cargoes.

Coal is a reviving export commodity, a quantity of which now moves in specially designed vessels coastwise to the large power stations and gasworks located along the banks of many U.K. rivers, serving populous areas. Coal for export abroad and that for coastwise carriage is loaded mechanically often assisted by gravity. The Tyne and Wear use gravity shoots and conveyors, Blyth, conveyor belts fed by mechanical truck tippers and Welsh ports high-level truck lifts with tipping gear. Anti-breakage appliances are used.

Discharge is at specially equipped jetties, using large capacity electrically operated grab cranes. The grabs are loaded by dropping on the cargo and then shutting them. The coal is trimmed out in the hold towards the centre of the hatch. The grab when loaded is released over a hopper feeding a conveyor belt carrying the coal to storage bins.

Ports not specially equipped for coal handling use light skips of metal or large wicker baskets, handled either by shore crane, crane or winch barge alongside to barges or by the ships' cargo winches. Gangs load the skips or baskets in the ships or barges holds which are then passed overside.

For bunkering or loading small quantities of coal as cargo, a floating mechanical elevator, with a grab loading a hopper on the pontoon from barges alongside, is employed. A vertical bucket conveyor feeds coal from the hopper outlet to a belt conveyor carried on a movable boom placed horizontally, and high enough to allow for movement horizontally and vertically for the varying height of ships' side and hatch in order to avoid much trimming.

Compared with grab handling, the skip method is expensive both in man power and cost.

Grain is discharged from steamer to barge by a floating pneumatic elevator (pneumatic discharge has almost superseded the bucket elevator) or from ship alongside direct to a specially built and ventilated grain store (a silo) by stationary pneumatic elevator plant located at the berth.

Grain for the provinces if there is lack of mechanical discharging facilities at the receiving point may have to be bagged. This may be done at the dock or wharf at the time the pneumatic elevator is discharging the grain.

Experiments made in the conveyance of bulk grain by railway box truck has, due to special equipment required at the receiving point, a restricted usefulness.

Only a large provincial miller can afford to instal expensive pneumatic mechanised equipment to discharge bulk grain from barge, or truck and his business would have to be considerable to keep the plant employed continuously.

Frozen and Chilled Meat and Provision Cargoes. Mutton from New Zealand, Australia, etc., is carried in refrigerated (i.e. at a temperature below 32° Fahrenheit) insulated cork lined hold compartments, with pre-cooled brine circulating round coils fitted therein. Beef from South America moves in "chilled" insulated holds. Pre-cooled air is blown through them by means of fans and air ducts for temperature control slightly above 32° F.

Frozen mutton may be discharged by canvas loop conveyors often at specially equipped berths, if there is a steady and continuous trade. The meat passes off the conveyor through a specially laid out transit shed for weighing, sorting and tallying and then into a cold store, or if for immediate delivery to an insulated barge, road van or railway truck for carriage to inland cold store. All of these conveyances with any dunnage, etc., have to be pre-cooled before loading to within a degree or so of the temperature of the ship's hold, otherwise the cargo will be ruined.

Frozen mutton and lamb may also be handled by quay crane or ship's gear, using specially designed canvas slings or rope nets so that heat by friction or rubbing by ropes or slings is minimised.

Chilled beef is handled by crane or ships' gear in specially

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designed canvas slings or rope nets. Where a considerable quantity is handled special conveyors may be provided wide enough to deal with the large "fores" or "hinds" laid flat. Pre-cooling of receiving vehicle is necessary here also.

Dairy produce, i.e. butter, eggs, cheese, etc., are carried in refrigerated compartments. Fluctuating temperature levels between ship and vehicle have to be avoided, for a difference of two or three degrees may cause serious damage.

Handling is by crane and boards, most of the commodities being either crated or cased.

"No temperature differences" (i.e. between ship's compartment and receiving vehicle) is the rule to be observed for all refrigerated and chilled cargoes. Every commodity has an "optimum" temperature at which it should be carried to ensure good out-turn. All handling and operations at normal temperatures have to be performed with all possible speed.

Bananas in full shiploads to a port where there is a fairly steady traffic are usually dealt with at a specially mechanised berth having several vertical canvas loop conveyors (each loop taking one "stem") extending down into the hold. These conveyors have a horizontal section leading ashore with another vertical loop section feeding a belt running at a suitable height parallel with and the length of the transit shed. Specially ventilated railway wagons are loaded by hand from this continuous belt, the bananas moving inland by rail to special storage depots to complete ripening and for distribution. Banana holds are usually kept to a temperature of around 55°F. Special quays have to be reserved for this traffic due to the loop and long quay conveyor belts. Bananas lend themselves particularly to handling by conveyor, each "stem" being similar in size and weight.

Timber, both softwood and hardwood, are difficult to handle due to the very varying shapes and sizes of each piece.

Softwood moves in full shiploads during the season from Scandinavian, Baltic and White Sea ports. Timber from the Pacific Coast (Oregon pine and partly processed timber articles like barrel staves, etc.) move in fairly large parcels. Plywood from Sweden and West Africa can be a heavy traffic. Hardwoods (mahogany, teak, etc.) move in parcels. All full shiploads are handled at specially selected sites in dock or wharf areas having large storage and sorting space available. Cut timber is often handled by special personnel who carry it ashore on their shoulders. Pitprops and hardwoods are handled by crane or ships' gear. Stowage ashore is by stack specially built to admit air, the more valuable timber being protected from weather by roofed open-sided sheds.

Timber is usually loaded to specially designed canal craft or railway wagons, for conveyance to privately owned timber wharves located on the banks of inland waterways or inland yards.

Bulk Oils. The handling of bulk cargoes of petroleum in ocean-going tankers has already been referred to. Both high (i.e. above 73°F.) and low flashpoint bulk oil cargoes (petrol, benzine, etc.) are usually handled in open river or estuary at berths with specially designed fireproof steel or reinforced concrete piled jetties, the oil being pumped ashore by the ship or by shore pumps through pipelines carried along the jetty to specially designed storage tanks.

Armoured hoses connected to standpipes on the jetty head are passed into the ships' cargo tanks through a deck "hatch" of the hinged steel type (often not much more than a large manhole) of the tanker.

Before unloading low flashpoint oil, compressed air is blown into the ships' tanks to rid them of vapour before pumping starts.

If oil of a heavy and viscous nature is being dealt with steam is passed from the shore through heating coils placed close to the standpipe suction near the bottom of the compartment to render the oil thinner and save pumping costs.

If a loaded tanker carrying high flashpoint oil (i.e. above 73°F.) wishes to discharge cargo at a place upstream of the normal "Petroleum limit" in a port, a chemist's certificate from the port of loading must be furnished to the harbour authority giving the flashpoint of the oil as determined by certain laid down tests. This certificate has to be countersigned as to the chemists' qualifications, etc., by the local British Consul at the port of loading. The object is to ensure that the flashpoint of oil is above 73°F.

Sugar is becoming a bulk cargo nowadays, due to the difficulty of obtaining suitable close texture bags. Quantities of refined or partly refined sugar move coastwise between dock and riverside wharves. Bagged cargoes are handled at a riverside wharf berth or at a mooring off shore, the cargo going overside, using rope slings for handling the "sets." No hooks for piling in shed or stacking in barge must be used, and any cargo spilled on the quays is swept up and sent to the refineries for treatment. H.M. Customs are concerned with the handling of sugar from foreign and colonial sources as a dutiable commodity. Bagged sugar has to be worked under cover in bad weather.

Partly refined sugar in bulk is discharged by grabs without teeth and as the result of experience gained with certain experimental voyages, modern wharfside refineries are now being equipped with specially designed layouts, with grab cranes (one per hatch) each feeding a hopper beneath the mouth of which runs a conveyor belt carrying the sugar direct into the refinery. The working area is completely covered, permitting discharging to proceed whatever the weather.

General and Export Cargoes. Single storey sheds (known as transit sheds) are provided at general and export cargo quays. Transit sheds provide protection for sorting and handling imports before delivery to conveyance or warehouse, or for receiving and holding export cargo before the ship arrives or is ready to receive.

The quay itself should be wide (modern ideas incline to a width of 100-ft.) having recessed railway tracks with the waterside track passing beneath the portals of the quay cranes. The object is for the handling of immediate delivery cargoes or loading direct from or to railway wagons, either by quay cranes or ship's gear.

Sufficient portal electric cranes to permit of one being allocated to every hatch of the vessel. If the quay is narrow and it is not desired to cumber it unduly with portal cranes, it may be equipped with semi portals, i.e. the front portion of the portal is carried on a sunk quay rail and the rear portion is carried on a rail placed off the quay on a shed or warehouse roof, the front of the shed being stiffened to take the weight. In both cases the quayside wheels of the cranes must be carried on rails as close to the waters edge as possible to avoid losing outreach.

Crane capacities vary greatly, depending upon the type of cargo handled, speed of quay clearance and a host of varying factors behind the actual quay itself, but modern ideas fluctuate between the 3-ton and 6-ton capacity crane having an outreach of between 50—70-ft. Some quays are equipped with both capacities.

Fixed quay cranes or wall cranes are of little use for cargo handling work on ships owing to the frequent necessity of altering positions to suit hatches during working.

A good supply of mobile electric or mechanised trucks is essential for expeditious handling and recent practice favours (where convenient) the use of fork-lift trucks and stackers using pallets, particularly for handling small cased units between shed and quay.

For exports it is usual to mark out on the floor of the transit shed certain areas for the reception and stacking of cargo for a particular (named) port. For import cargoes, this method is sometimes adopted for convenience where a cargo having a series of marks is being handled.

The golden rule for all quays and transit sheds is that cargo be cleared from both at the earliest possible moment. If congestion on quay or in shed arises the ship may have to stop work until space is cleared for the reception of further cargo.

Heavy lifts (i.e. exceeding the capacity of the largest quay crane on the berth) may be dealt with by a floating crane of the required capacity, although some older dock and wharf layouts make use of a fixed heavy lift crane, which places the load delivered to it on a barge, which is then placed alongside the ship, the cargo being loaded by the ship's heavy derrick. For import lifts this procedure is, of course, reversed.

4. Road, Rail and Inland Waterway Connections with Ports, Lighterage Facilities

The advantages and limitations of the road vehicle as a port feeder. The sphere of the railway as a port feeder. The limitations and advantages of canals and navigable waterways as port feeders. Inland navigation and estuarial craft types and methods of working. Lighterage in open estuaries and roadsteads.

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Road services to and from a port are perhaps the most flexible of all port feeders, although more expensive for bulk commodities than either railway or water transport, as the carrying units are so much smaller. The economic sphere of road transport may be said (for the mechanically propelled vehicle) to be up to 50 miles from the point of loading. For loads up to three tons it is quick and convenient, and for awkward "out of gauge" loads (i.e. of a weight or size difficult or impossible by rail) it is often the only method of transport practicable. Special carrying units are used.

The horse-drawn vehicle, although fast yielding to the mechanical unit, still has its useful sphere for collection or delivery of small parcels, and where considerable periods of waiting occur (such as during the loading of an export vessel). Horse transport is cheap, and the idle capital represented during waiting periods is not so great as in the case of the powered vehicle. Certain ports of the U.K. have in the past made discriminatory charges against road-borne traffic.

The railway handles merchandise of high and low values, but in general tries if it can, to secure high or medium valued merchandise which usually moves to and from ports in small quantities eminently suitable for rail carriage. Rail terminal charges (i.e. loading, unloading and handling costs) are high when compared with rail haulage costs, and a "short haul" (i.e. small mileage, terminal to terminal) is expensive, the total cost per ton per mile being high. A longer journey (say 50 miles or over) spreads the terminal charges, making the overall cost per ton per mile more reasonable.

For distances of 50 miles or more from the port the railway is usually (but not always) cheaper than its principal competitor, the road. Rail transport is expensive compared with road transport for small bulky consignments of less than one wagon load, and more expensive than water transport for bulk materials. Such comparisons must take cognisance of speed of transport, proximity of canal delivery point to destination (it might be necessary to use road transport for final delivery) and value of goods, which may be at risk for a longer time.

Inland waterways afford a cheap but slow means of transport. Goods are at risk for a longer period than in the case of other methods of transport and only low value bulk commodities, timber, coal, stone, etc., are usually carried any distance by water transport, although certain ports (London is one) have a "custom" whereby goods are taken into and out of dock by barge from and to a railway terminal wharf with inland rail connections. A barge can pass into and out of any enclosed dock owned by the P.L.A. free of dues, if for loading or discharging, provided its stay in dock does not exceed three consecutive tides. It is thus cheaper to take provincial traffic by delivery "overside" (i.e. handling them at ship's side away from the quay) from vessels in dock, delivering goods by barge to river railway wharf on the Thames than it is to pass over quay, land, and deliver them to railway truck or road vehicle in the dock area. Larger quantities are moved (one barge load represents many railway trucks, and still more road vehicles) and road and rail congestion near London is avoided. London is a "barge" port, 85% of its trade being dealt with by water transport up and down the Thames. At Bristol inland water transport handles large consignments of grain, etc., moving to the Midlands via the Severn and interconnected rivers and canals.

The great drawback of the British canal system is its differing widths, depths and lock dimensions. Transhipment to lighter drafted and narrower craft has to be resorted to for "through" traffic, which militates against the use of canals except on certain specialised routes. The Docks and Inland Water Transport Executive are tackling this problem, but at present boats of 14-ft. beam only can use a very small proportion of the canal routes and large stretches still in use can take boats no wider than 7-ft. beam and 70-ft. or less in length.

Draft restrictions and lack of water, especially in summer are other drawbacks, and ice in winter can cause serious delays.

A horse-drawn canal barge carries about 30 tons or so fully loaded, but with the gradual displacement by powered craft, towing a "butty" a load of 50 tons or so can can be handled.

Most ports (other than London) charge dues or locking fees on all barges and tugs using their enclosed docks. Some charge barge owners an annual fee based on measurements and tonnage. Craft registered with the Port Authority, Canal owning or other body are entitled to all facilities of the port. Canal authorities charge "locking fees" on each occasion a craft uses their locks.

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(To be continued)

Electrical Improvements at South Wales Ports.

It was recently announced by the Docks and Inland Waterways Executive that a programme for new works at Cardiff, Swansea and Newport Docks, estimated to cost £525,000, has been authorized by the British Transport Commission. The electrical services in the three dock areas are to be modernized, and the work involves the replacement of steam pumping and hydraulic plant by electrical equipment. The work is expected to take four years to complete and the improvements will result in a substantial fuel economy.